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DSTL, ADM 220/1739, 19 Oct 2009; DSTL, ADM 220/1739, 19 Oct 2009

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NO. 780.

CENTRAL RADIO BUREAU
REF. 47/. 92

ATI No. 9393

Incl. to
KO-72747

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE PERFORMANCE OF SHIPBORNE FIXED CROSSED LOOP H/F D/F APPLIED TO AIRCRAFT NAVIGATION.

BY

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No. 37.

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ADMIRALTY SIGNAL ESTABLISHMENT,

RESTRICTED

OCTOBER, 1946.

THEORETICAL AND EXPERIMENTAL INVESTIGATION OF THE PERFORMANCE OF SHIPBORNE FIXED CROSSED LOOP H/F D/F APPLIED TO AIRCRAFT NAVIGATION.

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Figures.

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1. GENERAL.

1(a) Operational Report.

The following signal (021137B May 1944) was received from the Escort Carrier H.M.S. TRACKER. "H/F D/F bearings taken of aircraft require different corrections to bearings taken of surface transmissions".

A tentative answer (041317B May 1944) to the above signal suggesting a modified D/F procedure for aircraft navigation was made pending investigation. The special procedure advocated is given in Clause 5 of the signal;

"Pending the results of trials, aircraft should be instructed, when D/F bearing is required, to complete an orbit x while transmitting, and the bearing given should be the mean of the extreme bearings"

1(b) Operational Requirements.

The development of the existing naval H/F D/F outfits resulted from the operational requirement of obtaining bearings upon H/F transmissions from surface vessels. It appears desirable to investigate the possibility of utilising the fixed crossed loop H/F D/F outfits, (FH3 and FH4) at present installed in Fleet and Escort Carriers to assist in the navigation of carrier-borne aircraft for homing, range estimation and taking fixes. This is a matter of some importance, particularly as the development of other types of D/F aerial systems, which reduce polarisation errors and are also suitable for employment at sea, has met with considerable difficulty.

1(c) Errors in D/F Bearings of Aircraft.

It is well known that correction is made for the site errors occurring with shipborne H/F D/F outfits by a standard surface calibration. These site errors are due to the production of a secondary field re-radiated from the ship's

/hull....

x This proposed special D/F procedure will be referred to subsequently as the "orbiting method".

hull and super-structure, and their magnitude depends upon the intensity and phase of this secondary field relative to the primary. In the case of aircraft transmissions, the phase and magnitude relationships between the primary (composed of the direct and ground-reflected waves) and the secondary (re-radiated) fields alter according to the angle of elevation of the aircraft. Consequently, in general, the errors will differ from those encountered in the surface calibration at the corresponding frequencies and can attain greater magnitudes. The calibration curves will be further affected by polarisation errors (so-called "aeroplane effect" errors), the magnitude of which will be dependent upon the type of aircraft transmitting aerial and which will increase with aircraft elevation. These factors, affecting the magnitude of errors arising when shipborne H/F D/F outfits are used for taking bearings of aircraft, are discussed in greater detail subsequently.

1(d) Purpose of Investigation.

In pursuance of signal 041317B it was decided to carry out a theoretical and experimental investigation of the performance of shipborne crossed loop H/F D/F when applied to the problem of aircraft navigation. This was principally undertaken,

(i) to determine the limitations of normal D/F procedure (i.e. that used for surface transmissions) when applied to aircraft navigation,

(ii) to verify that the suggested modified D/F procedure provides a greater degree of accuracy than the normal procedure when bearings are being taken upon aircraft transmissions.

2. THEORETICAL INVESTIGATION.

2(a) General.

When an aircraft is transmitting during flight and its bearing is determined by means of a direction finder of the simple rotating loop or fixed crossed loops type, errors, which are generally serious at short distances, may arise in regard to

/the.....

the determined bearing. This phenomenon is known as "aeroplane effect."

For a direction finder of the loop type, mere inclination of the direction of travel of the incident wave will not alone produce errors or blurring of the determined bearing provided the electric vector of that wave remains in the plane of incidence, x i.e. provided the incoming wave is plane polarised with its electric vector in the plane of incidence (normal polarisation). Unless the D/F aerial system is specially designed, however, the presence in the electromagnetic field of an electric component perpendicular to the plane of incidence / at the direction finder (abnormal polarisation) causes, generally, a deviation of the true bearing of the transmitter accompanied by blurring ϕ.

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x In terms of the magnetic vector of the field at the direction finder this consequently requires that the magnetic vector should remain perpendicular to the plane of incidence.

/ This component can arise, of course, even though the incident wave be plane polarised, and will always be present when it is elliptically polarised.

ϕ Exceptions to this general statement arise if

(i) the electric component perpendicular to the plane of incidence is in phase with the component in the plane of incidence or this latter component is absent. Under these conditions, of course, the wave is plane polarised. There is then deviation, but no blurring.

(ii) The horizontal electric component is in phase quadrature with the component in the plane of incidence, when there is blurring but no deviation. (The incident wave is then elliptically polarised but generally such polarisation will produce both blurring and deviation).

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Such polarisation errors are not eliminated by direction finders employing either a simple rotating loop or fixed crossed loops, and, consequently, the possibility of their occurrence is to be anticipated whenever such D/F systems are used.

The form of aerial generally adopted in modern aircraft is of the inverted -L type. This usually consists of a short vertical portion (of the order of 0.6 to 0.8 metres long) and a horizontal portion (of the order of 5 metres long), running roughly parallel to the fuselage of the plane and towards the tail. The vertical portion of the aerial is usually set at some distance from the nose of the machine.

Formerly, long trailing aerials were much in use and it was from observations of transmissions from these that errors due to aeroplane effect (in some cases very considerable) were first reported. With modern demands, however, such aerials have largely fallen into disuse and are employed now only in slow-flying aircraft.

For H/F transmissions from aircraft, a short vertical aerial is sometimes adopted.

Considering, for the moment, the distribution of current in the aerial alone, the inverted -L and trailing types mentioned above, when used for transmitting from an aircraft, clearly propagate a wave which, incident upon the direction finder, will contain a component of electric field perpendicular to the plane of incidence. The possibility of abnormal polarisation cannot be overlooked even when a vertical transmitting aerial is employed since, whenever an aircraft transmitting with such an aerial is banking or changing height, the conditions are just those causing the presence of a horizontal component (under such circumstances the conditions produced by a short vertical aerial and a trailing aerial become analogous).

In addition to these aerial currents, the return currents in the structure of the aircraft will themselves contribute to the magnitude and nature of the radiated field.

/For.....

For the case of a long trailing aerial, it is reasonable in so far as their effect upon the radiated field is concerned, to neglect the contribution of these structure currents since in whatever part of the structure they flow, their "effective height" is necessarily small compared with that of the aerial currents. For an aircraft employing an inverted -L aerial, however, no such assumption may, with a reasonable approximation of the true state of affairs, be made. While it is to be realised that the current will be distributed over both fuselage and wings, it is clear that the capacitative effect between the horizontal part of the aerial and the adjacent part of the fuselage will cause a considerable proportion of the return current to flow along this part of the structure, the remaining part being contributed by a flow along the wings and the part of the fuselage forward of the vertical portion of the aerial (see Fig. 1). It is considered that for the average type of inverted -L aerial not more than 20% (in the most disadvantageous case) of the current in the horizontal limb of the aerial is unbalanced by the return current in the adjacent part of the fuselage.

The transmitting aerial of an aircraft, together with the aircraft structure, constitute generally, therefore, a complex oscillator propagating a direct wave which, incident at the loop direction finder, contains in addition to an electric component in the plane of incidence (normally polarised component), an appreciable electric component perpendicular to the plane of incidence (abnormally polarised component) which may or may not be in phase with the normally polarised component.[x] The effect of this component will generally be complicated by the corresponding component in the

/wave.....

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[x] In general, it is to be expected that the normally and abnormally polarised components will not be co-phasal - i.e. the received wave will be elliptically polarised.

wave reflected from the ground. Under these conditions, the state of affairs arising at the direction finder is of a similar character to that produced by the more familiar case of a transmission containing an appreciable "sky-wave" component.† The analogy between "aeroplane effect" and "night effect" must not, however, be carried too far, since they are due to entirely different causes and, in the former case, steady conditions arise at the direction finder, whilst in the latter, the effects are of a transient nature. It is therefore to be expected that aeroplane effect will manifest itself by a constant or (due to the motion of the aircraft) steadily varying deviation of the D/F bearing and considerable blurring whilst, with night effect, it is well known that a wandering bearing and variations of blurring are encountered, even when bearings are taken upon a stationary transmitter.

As indicated in paragraph 1(c) in addition to "aeroplane effect" errors due to the abnormal polarisation of the primary (direct and ground-reflected) fields, the problem of direction finding on aircraft when shipborne H/F D/F outfits are employed is further complicated by site effect. The phase and amplitude relationships between the primary field and the secondary field, re-radiated from the ship's hull and superstructure, depend upon the angle of elevation and polarisation of the primary field. This results in site errors different from those encountered in the surface calibration at the corresponding frequencies.

2(b) <u>Concept of the "ideal" trailing aerial in free space</u>

It is, perhaps, not out of place to state here the complete problem* which presents itself in considering any attempt to calculate the "aeroplane effect" errors produced when bearings are taken with a loop direction finder upon a transmission from an aircraft in flight.

---

† In so far that both are polarisation effects. "Sky-wave" is the result of reflection from the ionosphere.

* Excluding the problem of site errors which will be discussed later

A complete solution of the problem resolves itself into a consideration of the following:-

(i) The determination of the distribution of currents in the transmitting system, viz. the aerial and the aircraft structure.

(ii) The calculation of the field of the direct electromagnetic wave at the direction finder due to this current distribution.

(iii) The calculation of the total (primary) field at the direction finder due to this direct wave and the wave reflected from the ground.

(iv) The errors in D/F bearing and the blurring which will arise from the presence in this total field of an electric component not in the plane of incidence of the direct (or ground-reflected) wave.

The obvious difficulty and complexity of such a task makes it apparent that to attempt to solve the problem without very considerable simplification is impracticable.

It has been shown* that, for an "ideal trailing aerial (neglecting for the moment, ground-reflection), the D/F bearing actually obtained with fixed crossed loops, is that of the point where the line of trail meets the horizontal plane (see Fig. 2). The term "ideal" is applied here to indicate that the line of trail is assumed to be straight and also that the return currents in the aircraft structure do not contribute to the radiated field. In other words, the "ideal" trailing aerial corresponds to an isolated dipole in free space. (These conditions are more or less satisfied in the case of L/F and M/F transmissions from a long trailing aerial). Under such circumstances the following conclusions regarding the order of magnitude of the resulting

/error....

* See Air Ministry Wireless quarterly report for quarter ending 31st March, 1934. "Location by wireless D/F methods of Aircraft at short ranges".

error (See Appendix 1) may be drawn.

(i) The error is zero only when the aircraft is flying in the plane of sight - i.e. either directly towards (homing) or away from the direction finder. This will be true for any height and distance of the aircraft from the direction finder - i.e. for any angle of elevation of the aircraft as measured from the direction finder.

(ii) For a definite angle of elevation of the aircraft from the direction finder, the error is independent of the distance, but depends on the direction of flight, and, for certain directions, passes through a maximum ϵ_m (see para. 2(i) and (ii)). These directions are not those giving the "broadside"† errors ϵ_b (see Appendix 1). The errors ϵ_m and ϵ_b and the corresponding directions of flight usually differ little one from another, but should be distinguished.

(iii) The magnitude of the maximum error diminishes as the angular elevation of the aircraft diminishes.

(iv) In particular, when the elevation of the aircraft exceeds a certain limit,‡ the maximum error, disregarding sense, is always 90°.

It should be noted that in the above discussion of the errors to be expected, it is assumed that the angle of trail of the aerial remains constant. For an actual trailing aerial, however, this angle will depend in practice upon the speed of the aircraft, so that the maximum error to be expected for a given elevation of the aircraft will also depend upon this factor.

Subsequently, it will be shown how a clearer insight into the more general problem of estimating the "aeroplane effect" /errors..

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† "Broadside" polarisation error is defined as the error occurring when the aircraft is flying on a transversal course (i.e. 90° from the line of sight).

‡ This angle α_s is the complement of the angle of trail δ of the aerial - i.e. $\alpha_s = 90° - \delta$.

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errors due to the inverted L type aerial in aircraft may be obtained by the application of the concept of an equivalent 'ideal' trailing aerial.

2(c) Effect of the presence of the Earth on the Polarisation Errors.

The considerations of paragraph 2(b) have been made ignoring the earth's effect upon the propagation of the waves. In practice, the magnitude of the errors cannot be predicted by considering the abnormal polarisation of the downcoming wave alone, since the actual field compared with the free-space field, will be greatly modified, the presence of the earth producing reflection from the surface and diffraction due to the curvature.

When the aircraft which is transmitting is within the optical range from the direction finder and the path of the direct ray is not too near to grazing incidence, the primary field may be obtained by applying optical ray theory (See Fig.3 and 4), and summing the fields of the direct and ground-reflected waves.

The magnitude and phase of the components* of the ground-reflected wave at the direction finder depend upon -

(i) the properties of the reflecting surface;

(ii) the height of the D/F aerial system above the ground;

(iii) the angle of incidence of the direct wave.

The curves of Fig.5 show the plane wave reflection co-efficients for sea water at 3, 7 and 16 Mc/s. For low angles of incidence the magnitude of the reflection co-efficient for the normally polarised component reaches a minimum at an angle of elevation** which in this band does not exceed 1°. Provided however, the angle of incidence exceeds approximately 5°, sea water may be regarded as an almost perfect reflector in the H/F band ......

** It is found considerably easier when dealing with problems involving the pick-up of loop aerials to base the considerations upon the magnetic vector of the field. Extreme care is necessary to avoid incorrect conclusions when considering the electric vector.

* The angle of incidence corresponding to this minimum, the so-called pseudo-Brewster angle depends upon the frequency.

band. Consequently, the aeroplane effect errors for a loop direction finder predicted in para. 2(b) are in this case only slightly affected by the sea-reflected wave.

In considering the effect of variation of the height of the D/F aerial above the earth's surface, it is necessary to take into account the difference in phase between corresponding components of the direct and reflected waves, caused by the fact that the two waves will have travelled different distances. It is, however, to be expected that, for any elevation of the D/F aerial system, the conclusions of the previous paragraph will hold, since in this case the reflected components will affect both the normal and abnormal polarised components of the direct field in a similar way to that in which they affect corresponding components at the earth's surface.

The curves of Fig. 6 and 7 have been drawn, assuming perfect ground-reflection, showing the magnitude of the total magnetic components as a function of height for various angles of elevation of the aircraft with an "ideal" trailing aerial, the angle of trail (δ) being 35°. It is seen that under these idealised conditions the horizontal components H_x and H_y of the magnetic field vanish together at certain heights above the reflecting surface. (These will be called the "cancellation heights"). In the presence of the primary field alone, the D/F bearing is determined solely by the relative magnitude of these horizontal components so that at the cancellation heights the D/F bearing could not be determined because the signal would vanish. In practice, however, at these heights, the signal is received only on the secondary field produced by re-radiation from the ship's hull and superstructure. The cancellation of the horizontal magnetic components of the primary field occurs only at certain fixed heights; at other heights the direct and reflected waves can add. The superstructure can therefore be energised by these horizontal components as well as the vertical

/component..

component and produce a considerable re-radiated field at the loops, whilst the primary field is effectively zero. Under these conditions, of course, errors and blurring can be expected of any magnitude up to 90° rendering H/F D/F completely impracticable. The angle or angles of elevation of the aircraft at which the horizontal components of the primary field vanish, for a given frequency and height of D/F framecoil, will be referred to in future as the "cancellation angle" (or angles) for that height and frequency.

Similar reasoning to the above holds, to a certain extent, for reflection from a normal soil for sufficiently steep incidence (angular elevation of the aircraft exceeding approximately 45°). For less steep incidence, the normal and abnormal components of the ground-reflected field are of different phases and magnitude so that they will combine with the components of the direct field differently. This effect is especially noticeable below the pseudo-Brewster angle for either soil or sea reflections since in this case the resultant normally polarized component will be considerably reduced. In the H/F band the pseudo-Brewster angle is of the order of 12° for soil and 1° for sea so that this effect can be expected for angles of elevation of the aircraft producing almost grazing incidence of the direct ray. It is expected that variations of the errors and blurring from the values in free space might result.

When the transmitter is just within the optical range from the direction finder so that the direct ray approaches grazing incidence or when the D/F is not well within the diffracted field, ray theory is no longer valid. Theoretical considerations seem to indicate that the "aeroplane effect" errors (which would be negligible in free space) might become of appreciable magnitude. It was proposed, consequently, that part of the experimental programme should include a series of experiments to investigate the phenomenon under these conditions. /At ......

At ranges well outside the optical, the diffracted fields due to vertical (normally polarised) and horizontal (abnormally polarised) electric dipoles were computed upon the complete electromagnetic theory. These computations indicate that the normally polarised component of the field is overwhelmingly greater than the abnormally polarised component, and it is therefore expected that for such ranges, very small errors due to aeroplane effect may be anticipated.

2 (d) <u>Electrical Equivalent of Aircraft Fixed Aerial.</u>

So far only the theory of the "ideal" trailing aerial and the effects of ground reflections have been discussed. This gives an approximation to the case which is realised, in practice, by an aircraft transmitting at H/F and M/F with a long trailing aerial.

It has been pointed out in paragraph 2(a) that, for the inverted L type aerial, now almost universally adopted in aircraft (and, indeed for a short trailing aerial, it is not legitimate to neglect the effect of the aircraft structure currents in any attempt to obtain a simplified theory by which the approximate magnitude of "aeroplane effect" errors may be calculated under specified conditions. The aircraft structure currents have already been discussed in paragraph 2 (a), and Fig.1 indicates what is considered to be their distribution for an aircraft employing an average type of inverted -L aerial, assuming purely arbitrary amplitude relationships. It is considered that the currents making the main contributions to the radiated field are :-

(1) The current in the vertical portion of the aerial and the unbalanced current in the horizontal limb and (or) fuselage,

and

(2) the balanced currents in the horizontal limb and adjacent part of the aircraft structure.

A simplified electrical equivalent of the transmitting aerial and aircraft considered as a complex oscillator will then be given by

/(i).....

(i) the "ideal" trailing aerial equivalent to the current distribution (1).

(ii) the loop transmitter corresponding to the distribution (2).

Knowledge of the "effective height" and "angle of trail" of the former and "effective height" of the latter (both of which would naturally be expected to vary with frequency) would permit the calculation of the approximate magnitude of the "aeroplane effect" errors and blurrings to be expected for prescribed conditions of elevation and direction of flight of the aircraft.

Provided only the order of magnitude of errors is sought, the effect of the balanced currents in the fuselage and horizontal limb of the aerial may be neglected at the lower frequencies (below 10 Mc/s say). Assuming a typical aerial of the dimensions and current distribution given in para. 2(a), the effective aerial system can be considered as an inverted -L carrying a uniform current distribution, I, in the vertical limb and a triangular distribution (a rough estimate of the maximum value of the unbalanced component being 1/5 I)[x] in the horizontal limb. By considering the "effective height" of such an aerial, the system may therefore be replaced by an equivalent "ideal" trailing aerial inclined to the vertical at approximately 35° and, in view of the remarks above, the order of magnitude of the error to be expected for any height, distance and direction of flight may be readily calculated. (see para. 2f (iii)).

At the higher frequencies, the effect of the balanced currents may no longer be ignored and actual computation of the errors would require, in addition to the equivalent trailing aerial, consideration of the out of phase contribution to the field due to these currents. It has not been considered necessary to

/attempt..

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[x] In Fig. 1., for the sake of clearness of drawing, the currents are taken in entirely different proportions.

attempt to calculate the errors at these higher frequencies, particularly in view of the complication due to site error which arises in practice and has been discussed previously. It should, however, be realised that at these frequencies the errors and blurring will probably be in excess of those which would arise under identical conditions (with regard to height, distance and direction of flight of the aircraft) at lower frequencies.

2(e) Method of Experimental Determination of the Angle of Trail of the Equivalent "Ideal" Aerial.

With perfect ground reflection and in the absence of a secondary field due to site re-radiation, at any frequency, the angle of trail of the "ideal" aerial equivalent to (i.e. giving the same "aeroplane effect" errors as) a given type of aircraft and aerial can be experimentally determined. This is done by measuring the maximum or "broadside" error in the D/F bearing when the aircraft is flying at a known distance and height (i.e. a known elevation) and applying the corresponding formula of Appendix I. Actually the determination of this angle, from a knowledge of which (neglecting the contribution of the balanced currents mentioned above) it is possible to predict the order of magnitude of the "aeroplane effect" errors at any height and distance, is complicated by the presence of a site error in addition to the "aeroplane effect" error.

It appears that the most effective way to separate the site error from the "aeroplane effect" error in the case of shipborne D/F outfits, is to perform a calibration of the outfit with a transmission from the aircraft circling at a constant height and distance. The "aeroplane effect" error for this elevation may then be taken approximately as the average error occurring throughout a complete "swing". This is the "broadside" error. It is assumed that the average value of the site error throughout a "swing" is zero and that the two types of errors may be considered as "additive".

/2(f).....

2(f) Graphical Illustrations of "Aeroplane Effect" Errors.

Curves giving illustrative numerical data regarding the order of magnitude of "aeroplane effect" errors to be expected under various conditions have been drawn in Figs. 8, 9 and 10. In preparing these curves the effect of ground reflection has been neglected.xx

(i) Fig. 8 gives the maximum error in the D/F bearing as a function of the angular elevation of the aircraft for "ideal" trailing aerials of various angles of trail.

(ii) Fig. 10 gives the error in the bearing as a function of the direction of flight for various elevations of the aircraft (α varying from 10^o by steps of 10^o). In this case an angle of trail of 35^o is assumed.

(iii) Curves of the maximum deviation of the D/F bearing, as a function of horizontal distance of the aircraft from the direction finder, for an "ideal" trailing aerial inclined at 35^o to the vertical, have been plotted in Fig. 9. These curves are drawn for an aircraft flying at 1,000, 5,000, 10,000 and 20,000 ft., taking into account the earth's curvature. The errors may be regarded as an indication of the order of magnitude of the maximum errors which can be expected for a typical fixed inverted -L aerial.

3. EXPERIMENTAL INVESTIGATION.

3(a) General.

Sea trials were carried out between 1/8/44 and 14/8/44 in the Clyde Area with H.M.S. SALTBURN equipped with an H/F D/F outfit FH4 which employs fixed crossed loops. Air co-operation was provided by 739 R.N. Air Squadron operating from the R.A.F. Air Station, Ayr. During the first part of the trials, H.M.S. SALTBURN was accompanied by H.M. Drifter Flow.

3(b) Purpose of sea trials.

In an effort to substantiate the theoretical considerations

/of.....

xx This is equivalent to assuming that the earth acts as a perfect reflector.

of Section 2 and answer the problems of paragraph 1(d), it was proposed that the experimental investigation should consist of:-

(i) Determination of the equivalent angle of trail of different types of aircraft aerials at various frequencies and, for trailing aerials, various speeds of the aircraft. It was proposed to effect this by calibrations with aircraft transmissions of a fixed crossed loop H/F D/F installation in H.M.S. SALTBURN, elimination of the re-radiation errors being effected graphically. (See paragraph 2(e)).

(ii) Investigation of the effect on the calibration curves of varying elevation of the aircraft and of the possibility of aircraft-transmission calibration.

(iii) Investigation of the effect of the cancellation angle of incidence upon the calibration curves.

(iv) Determination of the accuracy of the normal D/F procedure applied to homing of aircraft.

(v) Determination of the accuracy of the "orbiting method" applied to aircraft navigation (homing and fixes).

(vi) Determination of the equivalent angle of trail of the aerial specially constructed for investigating the polarisation errors at grazing incidence.

(vii) Investigation of the polarisation errors at grazing incidence.

3(c) Ship's D/F Installation.

The cathode ray H/F D/F outfit FH4 was installed in H.M.S. SALTBURN, the fixed crossed loop framecoil S25B being set at the top of a 50-ft. combined lattice and pole foremast. (See fig. 11).

3(d) Aircraft Transmitting Installations.

Transmissions were made from a Fairey "Fulmar" and a Fairey "Swordfish" aircraft. The H/F aerials normally employed in both these aircraft are of the fixed inverted L-type. Additional tests were made employing a trailing aerial in the "Fulmar", Fig. 12, and an aerial specially fitted in the "Swordfish" for the purpose of investigating the polarisation

/errors...

errors under specialised propagation conditions. This latter aerial, details of which are shown in Fig.13, was designed to produce a high percentage of horizontal, polarisation in the centre line of the aircraft.

3(e) Frequencies

Transmissions were made on frequencies of 4.2, 6.45, 8.925, 14.625 Mc/s. The first three were the nearest available frequencies to the extremes and mean of the frequency band in operational use for aircraft. The latter frequency was adopted for the purpose of investigating the polarisation errors under the specialised propagation conditions mentioned in para.2(c).

3(f) Trial Procedure

The trials consisted of:-

(i) Calibration at the test frequencies of the D/F outfit FH4 in H.M.S. SALTBURN with transmissions from a surface vessel (H.M. Drifter FLOW).

(ii) Calibrations with transmissions from the aircraft circling at different heights and distances and employing the normal fixed and trailing types of aerials. *
(In the case of the trailing aerial "swings" made at a fixed height and distance of the aircraft from H.M.S. SALTBURN, i.e. at a fixed elevation, were repeated at different speeds).

(iii) Observations of the variation of bearings when the aircraft "orbited" on a fixed straight course at various distances up to 60 miles.

(iv) Observation of bearings during straight flights along the centre line of H.M.S. SALTBURN (5 miles out, return, and 5 miles in the opposite direction and return) employing the special aerial.

/(v) ......

* Owing to the uncertainty on the part of the aircrew of maintaining a nearly circular course about H.M.S. SALTBURN the elevation angle of the aircraft was measured simultaneously with the visual and D/F bearings.

(v) Observation of bearings as in para. (iv) but for flights up to 60 miles. During this part of the trials, continuous R/T V.H/F communication (120 Mc/s) between H.M.S. SALTBURN and the aircraft was maintained.

4. RESULTS AND ANALYSIS.

4(a) General discussion of the aircraft calibration curves.

With a given aircraft at a given elevation and for a given frequency, the curves of error and blurring could not be repeated with the same degree of accuracy normally obtained for surface calibrations. Typical examples of the actual variations encountered when attempting to repeat a calibration are given in Figs. 14-22 and may be compared with that of the surface calibration curves at the corresponding frequencies in Figs. 23-26.

This inaccuracy in repetition of a calibration would appear to be due to difficulty in keeping the aircraft at a constant elevation. A certain amount of the "scatter" of the observations may definitely be accredited to inaccuracy caused by the speed at which it was necessary to make the observations.

The curves given in Figs. 27-50 and to which reference will subsequently be made as the "aircraft calibration curves" have been derived by taking an average from several "swings", except in the cases where this variation from "swing" to "swing" exceeds 20°. (The mean angles of elevation of each set of swings are marked on the curves inside a circular arrow indicating the direction of circling of the aircraft). The calibration gave reasonable repetition of results and fairly smooth curves for different swings in all cases except the following:-

on 6.45 Mc/s for all aerials with the elevation of 35°;

on 8.925 Mc/s for Fulmar trailing and Fulmar fixed aerials with the elevation of 35°.

(see figs. 30, 31, 32, 33 and 34). An attempt to explain these anomalies is given in para. 4(c).

In general, the calibration curves obtained with aircraft

/transmissions...

transmissions exhibit the following characteristics when compared with the surface calibration at the corresponding frequency:-

(i) the corrections are increased throughout the swing by large polarisation errors, and the shape of the curve is sometimes substantially changed.

(ii) the average blurring is much increased.

Whereas for surface transmissions, on all V/S bearings and all frequencies, the sense indications were correct and reliable, for the aircraft transmissions the sense performance was erratic. For some frequencies and elevations the sense indications were definite and correct, whereas for others (over arcs and complete circles) it was unreliable and incorrect.

The aircraft calibration curves at 4.2 Mc/s exhibit no unusual characteristics (see figs. 27, 28, 29, 39, 40 and 41), the average correction showing a decrease as the elevation of the aircraft was diminished. Change of the direction in which the aircraft circled H.M.S. SALTBURN produced the expected reversal of the sign of the average corrections.

At 6.45 Mc/s the state of affairs is less straightforward. The curves for all three types of aerial show a similar behaviour to those at 4.2 Mc/s until an elevation of 35° is attained (see figs. 30, 31, 32, 42, 43, and 44). At this elevation taking of bearings is impossible over wide arcs due to the ellipticity of the trace on the cathode ray tube exceeding 80%. These arcs are marked "no bearing" on the curves. Over the arcs where bearings can be taken, the corrections are large and change sign, and there is a wide divergence in the value of the corrections during different swings.

At 8.925 Mc/s all the calibration curves except two are smooth and the mean error is much smaller than that obtained for the corresponding curves at 4.2 Mc/s and 6.45 Mc/s (see figs. 33, 34, 35, 45, 46 and 47). The two exceptions are for the Fulmar trailing aerial with angle of elevation of 35° (see fig. 33) and

/for.....

for the Fulmar fixed aerial with angle of elevation of 28°
(see Fig.34). These resemble some of the anomalous curves obtained at 6.45 Mc/s, although the repetition of results in different swings is much better.

At 14.685 Mc/s all curves resemble in shape those obtained at 4.2 Mc/s, but the main errors for the smaller elevations are much larger than those for corresponding elevations at 4.2 Mc/s. For the larger elevations the mean values are of opposite sign to those for lower elevations. This is contrary to what would be expected for pure "aeroplane effect".

4(b) <u>Determination of the equivalent angle of trail.</u>

The equivalent angle of trail, as defined in Fig. 2, is calculated from the formula (see Appendix 1, equn. iv)

$$\tan\delta = \pm \tan \qquad \text{cotan} \qquad \ldots\ldots (4.1)$$

where δ = equivalent angle of trail

ϵb - "broadside" polarisation error

α - angle of elevation.

The values of ϵb were determined for all aircraft calibration curves, except the anomalous ones, as the mean errors over the swing and the results are tabulated below.

/over......

TABLE 1.

Equivalent angle of trail for Fulmar trailing aerial.

Frequency f (Mc/s)	Elevation α x	Correction $= -\varepsilon_b$	Angle of trail δ	Mean δ xx
4.2	31° ↺	+ 52°	65°	
	10° ↺	+ 27°	71°	
	4° ↺	+ 10°	68.5°	66.5°
	4° ↻	- 8°	63.5°	
	12° ↻	- 24°	66.5°	
	33° ↻	- 54°	65°	
6.45	10° ↺	+ 23°	67.5°	68.5°
	4° ↺	+ 11°	70°	
	36° ↻	- 60°	67°	-
8.925	10° ↺	+ 3°	16.5°	19°
	5° ↺	+ 2°	22°	
14.685	35° ↺	+ 67°	75°	-
	10° ↺	80°	92°	-
	5° ↺	26°	99°	99°

TABLE 2.

Equivalent angle of trail for Fulmar fixed aerial.

Frequency f (Mc/s)	Elevation α x	Correction $= -\varepsilon_b$	Angle of trail δ	Mean δ xx
4.2	34° ↺	- 22°	149°	148.5°
	34° ↻	+ 23°	148°	
8.925	28° ↺	- 29°	134°	-
14.685	30° ↺	- 8°	166.5°	-

x The arrow indicates the direction of circling of aircraft. The sign used in equation (4.1) depends upon this direction, being positive for counterclockwise circling and negative for clockwise circling.

xx Unreliable results - i.e. those corresponding to the anomalous calibration curves are omitted in determining mean δ.

TABLE 3.

Equivalent angle of trail for Swordfish fixed aerial.

Frequency f (Mc/s)	Elevation α x	Correction $= -\varepsilon_b$	Angle of trail x	Mean δ xx
4.2	29° ↓	- 28°	135°	
	10° ↓	- 9°	138°	136°
	5° ↓	- 5°	135°	
6.45	10° ↓	- 37°	103.5°	
	[illegible] ↑	+ 34°	105°	104°
8.925	31° ↓	+ 21°	32.5°	-
	10° ↓	0°	0°	0°
	6° ↓	0°	0°	
14.685	33° ↓	+ 52°	27°	-
	11° ↓	- 85°	91°	91°

The values of mean δ are plotted against frequency in Fig. 54. There is an ambiguity of 180° in the determination of the angle δ, since the loop D/F aerial (without sense) does not discriminate between a transmitting aerial with an angle δ, and one with $\delta + 180°$.

As there were very few experimental points, an approximate analysis was carried out to give an indication of the shape of the curves. For this purpose an attempt was made to estimate theoretically the approximate current distribution in the aerial and fuselage and from this the equivalent angle of trail δ in each of the three cases.

The aerial current distribution can be easily determined in the usual way.

The distribution of current in the fuselage was determined by the superposition of two pictures:-

/(i).....

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x The arrow indicates the direction of circling of aircraft. The sign used in equation (4.1) depends upon this direction, being positive for counterclockwise circling and negative for clockwise circling.

xx Unreliable results - i.e. those corresponding to the anomalous calibration curves are omitted in determining mean δ.

..7.0.

(i) Return currents of the aerial in the fuselage;

(ii) Fuselage resonance currents due to independent oscillation of the fuselage acting as a half wave horizontal antenna excited by the return currents of the aerial. The effect of fuselage resonance currents was considerable in a wide band around the resonance frequency, while the return currents were the prevailing factor on the other frequencies, especially on lower frequencies where δ is constant as is the case in the L/F and M/F bands.

The direction of the fuselage resonance currents depends on :-

(i) The position of the aerial lead relative to the mid-point of the oscillating structure;

(ii) The amount of capacitive coupling with the aerial - i.e. the equivalent capacity between the aerial and each end of the fuselage;

(iii) The sign of the potential acting across these equivalent capacities.

Under these conditions the circuit can be treated as a capacity bridge in order to determine the correct direction of the current.

The resultant current distribution was obtained by assuming that both types of current were in phase which is true of most frequencies.

In order to find the equivalent angle of trail, the horizontal and vertical of the currents were determined and the corresponding "metre-amperes" obtained by graphical interpretation. The direction of the resultant vector of metre-amperes relative to the vertical, determines the required equivalent angle of trail.

This procedure was carried out qualitatively, and the results are shown in Fig.54. As an example, the analysis in the case of the Swordfish fixed aerial is given below :-

(i)/.......

(i) 4.2 Mc/s.

Only aerial and fuselage return currents are important. For triangular current distribution in the aerial, the direction of the resultant horizontal component of metre-amperes is towards the rear.

For the return currents in the fuselage the resultant horizontal component of metre-amperes is also towards the rear, on account of the longer path of the currents in the forward part of the fuselage.

(ii) 6.45 Mc/s.

As for 4.2 Mc/s, except that tail currents are reduced because of the lower voltages of nearby elements of the aerial. The rearward horizontal component is therefore larger and δ is nearer to 90°.

(iii) 8.925 Mc/s.

Fuselage resonance currents must be taken into account. (The fuselage resonates at about 9 or 10 Mc/s). The aerial current distribution is nearing that of the quarterwave mode, but the resultant horizontal component of metre-amperes still remains in the same direction (towards the rear). The resultant fuselage current is modified by the superposition of the fuselage resonance current directed forwards. (Because of the much larger capacity between the aerial and the tail part of the fuselage, this excitation will prevail, although the lead-in point of the aerial is nearer the tail).

The total resultant horizontal component of metre-amperes is practically zero; i.e. the equivalent aerial is approximately vertical.

(iv) 14.685 Mc/s.

Fuselage resonance currents are again small, and the effects are similar to those at 6.45 Mc/s, although the horizontal component towards the rear is relatively larger.

/4(c).....

4(c) Anomalies in Calibration Curves.

The only possible method of explaining the errors occurring in the anomalous curves is to assume that there is re-radiation from horizontal resonating loops, formed by the structure of the ship such as the hull, the boat deck and the bridge. This theory explains all the anomalous experimental results.

Let us consider a horizontal rectangular loop isolated in free space. In the presence of a vertical component of magnetic field the E.M.F. induced will produce large currents when in the resonant condition. This will occur when the loop perimeter (p) is one wavelength (λ) or a multiple of this ($n\lambda$). From a consideration of current distribution it can be shown that resonance cannot occur when $p = \frac{n\lambda}{2}$. The current distribution is decided from considerations of symmetry about the direction of incidence. Fig. 51a shows the 1st and 2nd modes of oscillation for the direction of arrival perpendicular to the longer side, together with the corresponding voltage distribution.

In the case of the 1st mode of oscillation the currents produce, at points lying on the vertical axis of the loop, a secondary field having its magnetic component horizontal and in the plane of propagation. This applies for any direction of arrival.

The magnitude of the secondary field is large because of the additive effect of the currents in opposite members, which contain the current antinodes.

In the case of the second mode of oscillation, the effects of currents in opposite members cancel along the vertical axis of the loop, and produce a relatively small secondary field at other points.

Similar reasoning applies to higher modes of oscillation and it can be shown that while odd modes can produce a large secondary field at points above the loop, even modes produce very little secondary effect in these positions. Therefore

/only.....

only odd modes of oscillation will be considered further.

Similar results will be obtained with a plane metal sheet as the H/F currents will be confined to the edges.

This also applies to a solid three-dimensional structure placed on a conducting plane when the horizontal roof or deck can still be excited by the vertical component of the magnetic field. The magnitude of the currents will, however, depend on the relative size of the supporting vertical structure, being maximum when this size is a quarter-wavelength. In a non-symmetrical structure, this last condition strictly speaking, only applies to the vertical supports directly beneath the voltage antinodes.

These considerations are also true for a long narrow structure as illustrated in figs. 53a, b and c. In the cases of higher modes of oscillation ($p = 3\lambda$, 5λ etc.), i.e. higher frequencies, the effects tend to cancel out at certain positions above the deck and add in other positions. This depends on the distances of the points considered from the various antinodes of current.

In the case of the first mode, the effect is independent of the horizontal direction of arrival, but for higher modes it becomes directive and the horizontal pattern is different for different angles of elevation of the incident field.

The presence of the conducting plane makes it necessary to consider also the reflection effect discussed in para. 2c. The magnitude of the vertical magnetic component varies sinusoidally with height, being zero at the reflecting plane (see figs. 6 and 7). The magnitude of the E.M.F. induced in the roof or deck therefore varies in a similar way.

This theory can now be used to explain the anomalies in the practical results.

<u>6.45 Mc/s.</u>

On this frequency the cancellation angle is 31°, and so for all angles of elevation near this value the horizontal /magnetic......

magnetic components of the primary field are almost cancelled, and the bearings obtained are determined solely by re-radiation effects. Owing to the rapid variation of horizontal components with elevation angle α in the vicinity of a cancellation angle, even a small variation in (e.g. 34° to 36°) can cause considerable differences in the correction curve. This is illustrated by the curves of different swings shown in Fig.30.

It is difficult to decide in this case which is the main source of re-radiation, as any type of re-radiator would give curves of the erratic form obtained. It seems, however, that resonance of the main deck as a horizontal loop (3λ mode of oscillation), makes some contribution to the errors. On this relatively low frequency, the currents in this horizontal loop are small because of

(i) the relatively small vertical component of the magnetic field at this height (See Fig.6);

(ii) the low impedance of the vertical supporting structure height (much less than $\frac{\lambda}{4}$).

8.928 Mc/s.

On this frequency the anomalous results occur for angles of elevation between 28° and 36° in the cases of the Fulmar trailing aerial and Fulmar fixed aerial.

Since the cancellation angle for this frequency is only 22°, and since no anomalous effect occurs with the Swordfish fixed aerial even with an elevation angle of 31°, the anomalies cannot be due to cancellation effects.

Two horizontal loops can resonate at this frequency, and these appear to be the cause of the anomalies. They are:-

(i) Boat deck ($p = 3\lambda$ See Figs. 53a and b).

(ii) Main deck ($p = 5\lambda$ See Fig. 53c).

Owing to the smaller magnitude of the exciting (vertical) magnetic component, the slightly greater distance from the D/F framecoil; the higher mode of oscillation, and the smaller

impedance/ ......

impedance of the vertical supports, the effect of the main deck resonance is considerably smaller than that of the boat deck resonance and can be ignored.

The rapid variation and change of sign in the anomalous correction curves for the Fulmar with trailing aerial can be explained by the directive properties of the oscillating deck.

Two particular cases are considered, for incidence athwartships (Fig. 53a) and along the fore-and-aft line (Fig. 53b) for an angle of elevation of 35°. In the first case, the phase difference between the field exciting the opposite edges is 44° and as the currents in the edges are in the same direction, this small phase difference will only slightly reduce the excitation. A similar consideration applies in the second case. Thus, excitation occurs for incidence along the fore-and-aft line and this is responsible for the large corrections on V/S bearings around 0° and 180°. As the magnetic component of the secondary field lies in the plane of incidence in both cases, and as the phase of the secondary field varies with the direction of incidence, large errors are obtained fore and aft, and large blurring and therefore no bearings are obtained athwartships.

The case of the Fulmar fixed aerial is not quite consistent with this explanation (especially the shape of the curve round 150°), but the data obtained is insufficient to allow any further analysis.

The absence of anomalous effects in the case of the Swordfish fixed aerial can be explained by the fact that its equivalent angle of trail δ on this frequency is 180° (vertical). Thus, no vertical magnetic component is present in the field and the horizontal loops are not excited. This case, also, supports the explanation in terms of the oscillation of horizontal loops.

<u>14.685 Mc/s.</u>

On this frequency all the curves are smooth and no large

/variations....

variations about the average error occur. There is, however, a change in sign of the average error as the elevation angle increases from 10° to 33° (figs. 36 and 38). This cannot be explained in terms of pure aeroplane effect taking sea reflection into account.

Measurements were made for elevation angles (5°, 10° and 11°, and 33°) different from the cancellation angles (13° and 42.5°) on this frequency, and so the results cannot be due to cancellation effects. Also, as seen from Fig. 7., the relative phases of H_x and H_y (horizontal magnetic components of the field) have the same sign for all elevation angles, and so the change in sign in the errors cannot be explained purely in terms of the primary field.

The omni-directional nature of the effect suggests that it is produced by re-radiation from a horizontal loop oscillator in the ship's superstructure situated almost symmetrically about the D/F mast and resonating in its first mode on or near this frequency. The bridge structure satisfies these requirements. A simplified diagram of the bridge structure of H.M.S. SALTBURN is shown in Fig. 51b, and it is seen that the semi-perimeter of this structure is approximately 11 metres. This will resonate as a full-wave horizontal loop oscillator at 13.6 Mc/s, and, since the structure is broad, the resonance peak will be correspondingly wide and may reasonably be assumed to embrace the frequency under consideration, 14.685 Mc/s.

The height of the vertical supporting structure is such that a considerable voltage will be maintained in the oscillating loop.

This oscillating loop will produce at the D/F framecoil, a magnetic field (H_1) which will always be horizontal and in the direction of incidence of the primary field. (i.e. in the direction of H_x). The magnitude of H_s at the bridge level is comparable with that of H_x and H_y at the D/F framecoil for both

/elevation.....

elevation angles, even for the small value of δ (35°), assumed in Fig. 7. The phase difference between H_z at the bridge level and H_x and H_y at the D/F framecoil is 0° for elevation angle 10° and 180° for elevation angle 35o (See Fig. 7). Thus, as shown in Fig. 51c, H_x and H_1 add at $\alpha = 10°$ and subtract at $\alpha = 35°$, and the vector diagram shows clearly that the sign of the error is reversed as a result of this.

It should be possible from these considerations to calculate the pure polarisation errors, and thus the equivalent angle of trail. The accuracy of these calculations is, however, very small owing to the large variations in the values of tan δ for small variations in δ when δ is near 90°. The equivalent angle of trail, therefore, was calculated for small elevation angles only, neglecting the small effects of the re-radiation from the bridge.

4 (d) Investigation of the Orbiting Method.

The data obtained during the test runs to investigate the possibilities of the 'orbiting' method are plotted in Figs. 56 - 59. These flights were made employing all three types of aerials with transmissions at 4.2 Mc/s, and the Fulmar trailing aerial only at 14.685 Mc/s. The graphs show the "D/F true" bearing obtained by correcting the D/F bearing from the surface calibration curve. A succession of observations was taken during each orbit and these are plotted as a function of time. A scale of distance has been correlated to the time scale by employing the navigational fixes obtained by the aircraft during flight. The curves of bearings obtained during the orbits are indicated by a dotted line. The error in the mean of the extreme "D/F true" bearings from the correct true bearing for each orbit is given in the accompanying graphs of "accuracy of the orbiting method".

Bearings were also taken between the orbits when the aircraft was flying along its prescribed straight course. The plots of these observations in the Figs. 56-59 are joined by a

/chain ......

chain dotted curve. It is considered that the errors which are quite considerable at the closer ranges are caused by "drift" of the aircraft. This would result in the transmitting aerial not lying in the plane of sight from the D/F loops and an error in the bearing would arise.

4(e) Anomalies in polarisation errors at grazing incidence.

An attempt was made using the special aerial (see fig. 13 and para. 3a) to ascertain whether any increase of polarisation errors occurs at grazing incidence as might be expected from the discussion in para. 2c. The experiments consisted of bearing determination for an aircraft in a straight flight out (80 miles) from H.M.S. SALTBURN and back. The special aerial, however, did not have the required equivalent angle of trail in the transverse direction and so the results of the experiments were useless.

Some information on this subject can be obtained, however, from the results of the orbiting experiments described in para. 4d., although these experiments were not carried out for this purpose.

This information has been obtained as follows:

The magnitude of the maximum polarisation errors at each orbit (half of the total bearing variation) for each aerial and height of flight were determined from Figs. 56-59 and plotted against distance (see Figs. 60-63). In each case, the apparent equivalent angle of trail (Δ - see para. 4f) was calculated from the formula (iii) in the Appendix I (substituting Δ for δ), for each point up to a distance of approx. 20 naut. miles. The average value of Δ was then found for each case. The measurements for distances greater than 20 naut. miles were not taken into account because beyond this distance the effects of grazing incidence were expected to appear, whereas at smaller distances the errors should be purely polarisation errors.

From the average value of Δ the theoretical curve of

/maximum.......

maximum polarisation error against distance was plotted for distances up to that corresponding to the aircraft horizon. It was expected that any errors due to grazing incidence effects would appear as an increase in the polarisation error above the value in the theoretical curve. The distance corresponding to the pseudo-Brewster angle for the height in question is marked on the curves.

There is good agreement between the theoretical and experimental values, both for the outward and return flights, except in fig. 60 at distances around that corresponding to the pseudo-Brewster angle. Here the experimental values are approximately twice as large as the theoretical ones, although these are small, being of the order of 2°. There is a similar tendency in the results shown in fig. 61, although there are very few points around the critical distance, while in fig. 62 and 63, because of the absence of points at this distance, no conclusions can be drawn.

It seems from this that certain grazing incidence effects do occur, but these appear to be relatively small. (Some surface wave can be expected for these heights of flight and this would reduce the errors obtained). Because of the smaller number of observations and observational errors comparable with the errors under investigation, however, no definite conclusions can be obtained. It is clear, however, that the effects are not serious from the practical point of view for the average type of aircraft aerial and the altitudes of flight investigated (up to 5000 ft.)

4(f) Effect of banking on equivalent angle of trail.

There is certain disagreement between the values of the apparent equivalent angle of trail (Δ) obtained from the orbiting results and the equivalent angle of trail (δ) obtained from the aircraft calibration curves. This difference in value is due to the banking of the aircraft while making circles of small diameter in the orbiting experiments.

/This..

This banking causes a variation in the horizontal and vertical components of the equivalent aerial as shown in fig. 64, and thus results in an apparent increase in the equivalent angle of trail. From the values of δ and Δ, the banking angle of the plane (β) can be calculated from the formula given in fig. 64.

For (using the symbols given in fig. 64).

$$\tan\delta = \frac{h}{v}$$

$$\tan\Delta = \frac{H}{V} = \frac{\sqrt{h^2 + v^2\sin^2\beta}}{v\sin\beta}$$

$$\text{Hence } \cos\beta = \sqrt{\frac{\tan^2\delta + 1}{\tan^2\Delta + 1}}$$

Values of β were calculated in each case and are given on the corresponding figures.

No observations were made to confirm these figures but they appear reasonable from consideration of the types of planes and their speeds.

5. CONCLUSIONS.

5(a) Limitations of the present D/F procedure when applied to aircraft navigation.

From the results of these trials, it appears that the present D/F procedure employed for surface transmissions is of little use for aircraft transmissions, since at distances less than approx. 30 miles polarisation effects and the anomalous effects described previously become too large, and beyond 30 miles there is the possibility of receiving sky wave components.

The possibility of providing a modified form of this procedure by carrying out calibrations with aircraft transmissions is impracticable owing to the large number of unknown variables, such as elevation and inclination of the aircraft, type of aerial. etc.

5(b) Improvement of Accuracy.

In order to improve the accuracy of the present H/F D/F outfits for use with aircraft, two possibilities appear to require consideration, although neither will give a completely /satisfactory..

satisfactory solution.

(i) Development for use in aircraft of a fixed aerial having pure vertical polarisation.

(ii) Application of the special D/F procedure, which requires "orbiting" the aircraft on the fixed true bearing. The required bearing is given by the mean of the two extreme readings corrected from surface calibration. This method can be applied with the existing D/F equipment and types of fixed and trailing aerials at present employed in aircraft.

5(c) Discussion of the design of a special transmitting aerial for use in aircraft.

A special aerial (mentioned in para. 5b(i)) requires complete symmetry about the vertical axis of the aerial system, including the aircraft structure itself acting as a counterpose carrying the return currents. This seems to be an impracticable solution as no existing aircraft conforms to this requirement. It would probably be possible, however, to find a site for the transmitting aerial giving a reasonable approximation to the requirement, at least for frequencies below the resonance frequency of the aircraft fuselage (i.e. approx. 8 Mc/s).

5(d) Application of the "Orbiting Method".

The second suggestion of para. 5b may be rather inconvenient in operation but, nevertheless, secures a reasonable accuracy in D/F. The experimental results confirmed a very large increase of accuracy even in the case of "homing" procedure. In the case of transversal flight, this procedure is indispensable for obtaining bearings of any reasonable accuracy.

5(e) Possibility of range estimation by the "Orbiting Method".

The same "orbiting method" might allow range estimation by the determination of the amplitude of variation of the bearings. A very large number of factors would have to be taken into consideration, however.

/These......

These include types of aircraft and aerials, frequencies, altitudes of flight and banking angle of the aircraft concerned.

5(f) Application of the results for the analysis of D/F on sky wave.

The explanations of the mechanism of the anomalous effects obtained in these trials find considerable application in the analysis of the possibilities of D/F on sky wave using shipborne H/F D/F outfits.

Errors will occur even with polarisation-free instruments because of:

(i) cancellation effect;

(ii) re-radiation of horizontal loop oscillators.

6. PROPOSED FUTURE TRIALS.

These conclusions apply qualitatively to the H/F D/F installations in aircraft carriers but because of the much larger corrections arising [illegible] surface calibrations of these vessels than were encountered in H.M.S. SALTBURN, the magnitudes of the effects may be larger. In the case of aircraft carriers, the surface calibration corrections are due mainly to re-radiation from the hull and the magnitude of this re-radiated field is particularly dependent upon the abnormally polarised components of the downcoming incident field.

In addition, the height of the D/F loops above the sea surface, which is larger in aircraft carriers than in H.M.S. SALTBURN, should be taken into account as the variation of the relative phases of the sea-reflected and direct waves with angle of incidence will be more critical in the case of aircraft carriers, i.e. more cancellation angles will occur for a given frequency.

It is considered desirable to carry out additional trials in an aircraft carrier equipped with outfit FH4. Such trials should be limited mainly to checking the accuracy of the "orbiting method", provided that this method is accepted for operational work. The repetition of a few calibration swings with aircraft flying on different elevations may be advisable.

The effectiveness of the "orbiting method" should be checked at the "cancellation angle" and the limitations of this defined.

/Special..

Special charts giving the "cancellation angles" for a given height of D/F loops above the sea surface and different frequencies should be computed and verified experimentally.

For theoretical interest the phenomena occurring at grazing incidence should be further investigated.

APPENDIX I.

Equation for aeroplane error (ε) in terms of elevation (α) and equivalent angle of trail (δ).

This is a well-known formula but is included here for reasons of clarity.

Notation (see Fig. 65).

h = height of the aircraft above the ground.

d = distance from direction finder to the vertical projection of the aircraft on the ground.

α = angle of elevation of the aircraft measured from the direction-finder

δ = angle which the "ideal" aerial makes with the vertical ("equivalent angle of trail")

θ = direction of travel of the aircraft relative to the line of sight (inclination).

ε = error in D/F bearing.

From Fig. 65.

$$\frac{\sin \varepsilon}{\sin (\theta - \varepsilon)} = \frac{h}{d} \tan \delta$$

$$= \tan \alpha \tan \delta \quad \ldots \quad \text{(i)}$$

$$\text{i.e. } \sin \varepsilon = (\sin \theta \cos \varepsilon - \cos \theta \sin \varepsilon) \tan \alpha \tan \delta .$$

$$\tan \varepsilon = \frac{\tan \alpha \tan \delta \sin \theta}{\tan \alpha \tan \delta \cos \theta + 1} \quad \ldots \quad \text{(ii)}$$

Values of ε against θ for various values of α and $\delta = 35^\circ$ are plotted in fig. 10.

Two special cases will be considered.

(a) When $\angle ACB = 90^\circ$ or 270° (i.e. $\theta - \varepsilon = 90^\circ$ or 270°)

In this case AC is tangential to the circle and ε is maximum (ε_m)

From (i) $\quad \sin \varepsilon_m = \pm \tan \alpha \tan \delta \quad \ldots \quad$ (iii)

(Positive sign corresponds to anticlockwise circling and negative sign to clockwise circling).

(b). When $\theta = 90^\circ$ or 270°. Here the direction of flight of the aircraft is perpendicular to the line of sight, and the value of ε under these conditions has been defined as the "broadside" error ε_b. This is the condition which occurs when an aircraft is circling round the

/direction.....

direction finder, and ${}_b$ is the value obtained by averaging the errors over a full swing in the aircraft calibration curves. (See para. 46 and Figs. 27-38).

From eqn. (ii) when θ=90° or 270°

$$\tan \theta_b = \pm \tan\alpha \tan \delta \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\text{(iv)}$$

(Positive sign corresponds to anti-clockwise circling and negative sign to clockwise circling).

When α is large compared with h tan δ., then

$\angle$ ASB + θ + 90° and in this case θ b = θ m

3.1

DISTRIBUTION OF AERIAL AND STRUCTURE CURRENTS IN AIRCRAFT

FULMAR – FIXED AERIAL

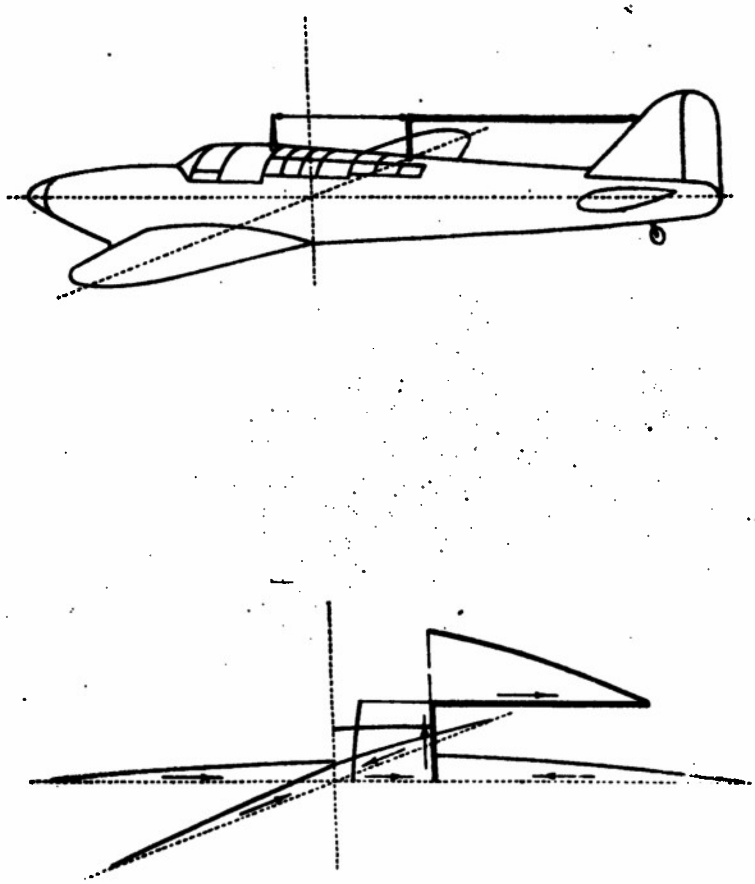


FIG. 1

GEOMETRICAL DETERMINATION OF AEROPLANE EFFECT ERRORS FOR AN 'IDEAL' TRAILING AERIAL ABOVE A PERFECTLY REFLECTING EARTH

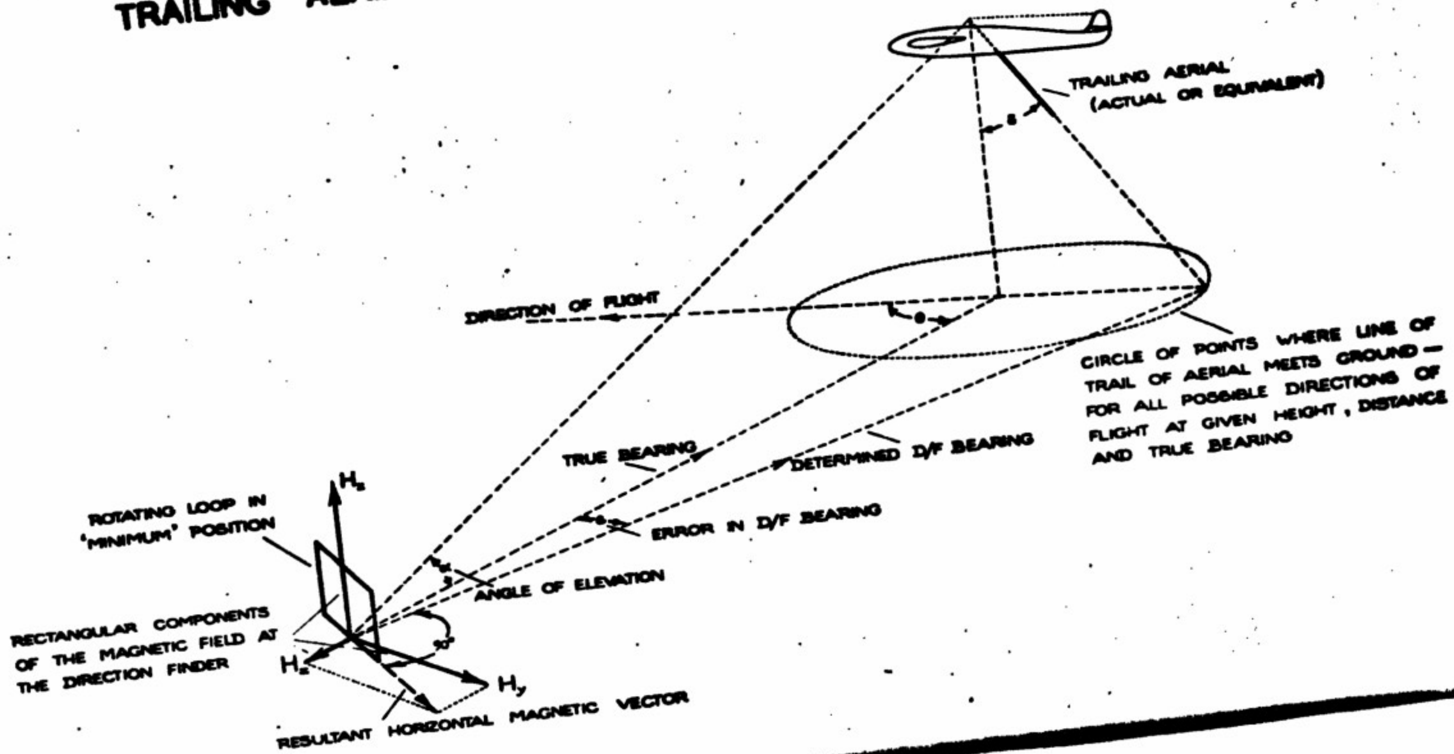


FIG. 2

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

GEOMETRY OF REFLECTION BY RAY THEORY

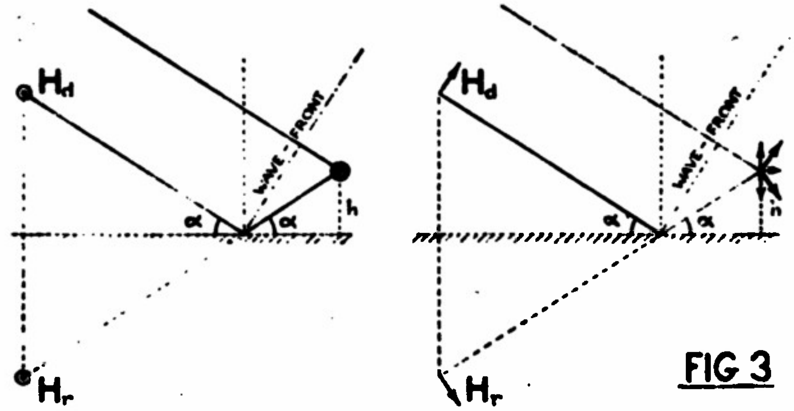


FIG 3

(a) NORMAL POLARISATION (b) ABNORMAL POLARISATION

(i) φ — PHASE SHIFT BETWEEN DIRECT (H_d) AND SEA-REFLECTED (H_r) FIELDS —— $\varphi = 4\pi \frac{h}{\lambda} \sin\alpha$

(ii) h_c' — CANCELLATION HEIGHT FOR VERTICAL AERIALS [FOR $\varphi = (2n+1)\pi$] —— $h_c' = \frac{\lambda(2n+1)}{4\sin\alpha}$

(iii) α_c' — CANCELLATION ANGLE FOR VERTICAL AERIALS —— $\sin\alpha_c' = \frac{\lambda(2n+1)}{4h}$

(iv) h_c'' — CANCELLATION HEIGHT FOR HORIZONTAL AERIALS. (FOR $\varphi = 2n.\pi$) —— $h_c'' = \frac{\lambda}{2}\frac{n}{\sin\alpha}$

(v) α_c'' — CANCELLATION ANGLE FOR HORIZONTAL AERIALS —— $\sin\alpha_c'' = \frac{\lambda n}{2h}$

MAGNETIC COMPONENTS OF THE DIRECT FIELD FOR THE IDEAL TRAILING AERIAL

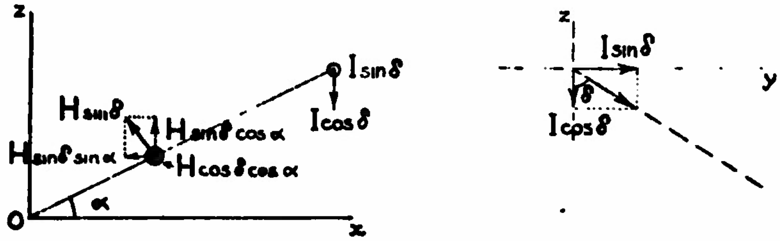


FIG 4

AMPLITUDE AND PHASE OF THE REFLECTION COEFFICIENTS AS A FUNCTION OF ANGLE OF ELEVATION FOR SEA WATER

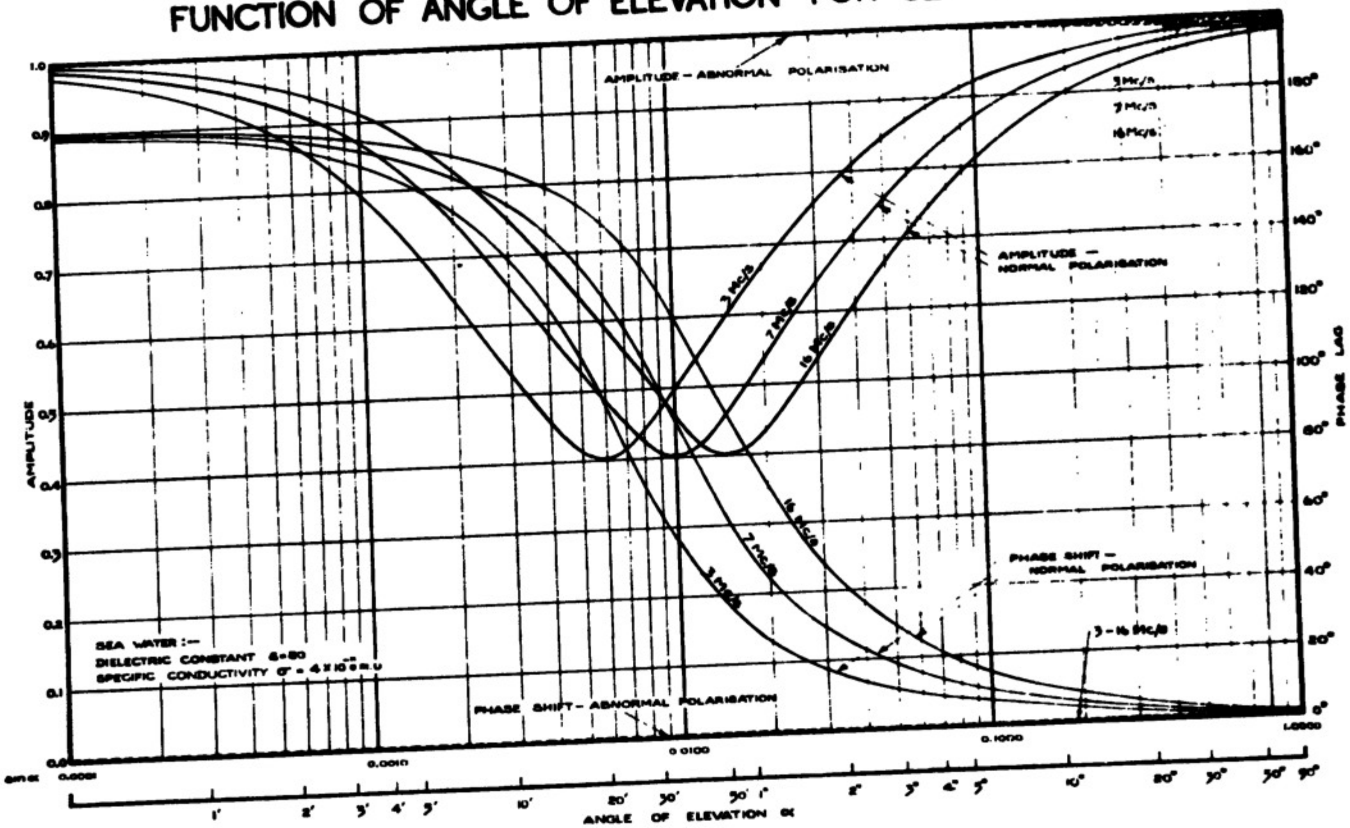


FIG. 5

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIELD COMPONENTS OF STANDING WAVE PATTERN PRODUCED BY DIRECT AND SEA REFLECTED WAVES FOR DIFFERENT ANGLÉS OF ELEVATION.

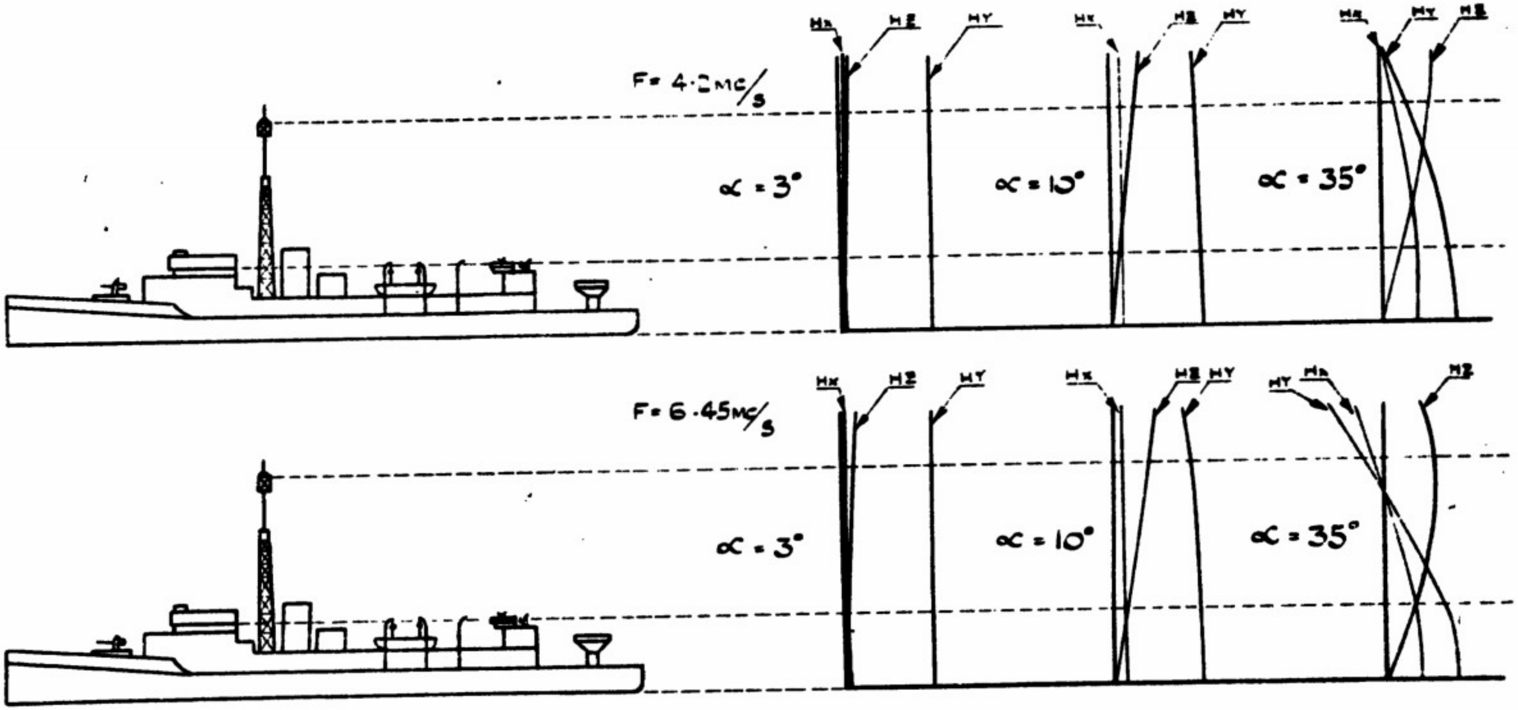


FIG 6

FIELD COMPONENTS OF STANDING WAVE PATTERN PRODUCED BY DIRECT AND SEA REFLECTED WAVES FOR DIFFERENT ANGLES OF ELEVATION.

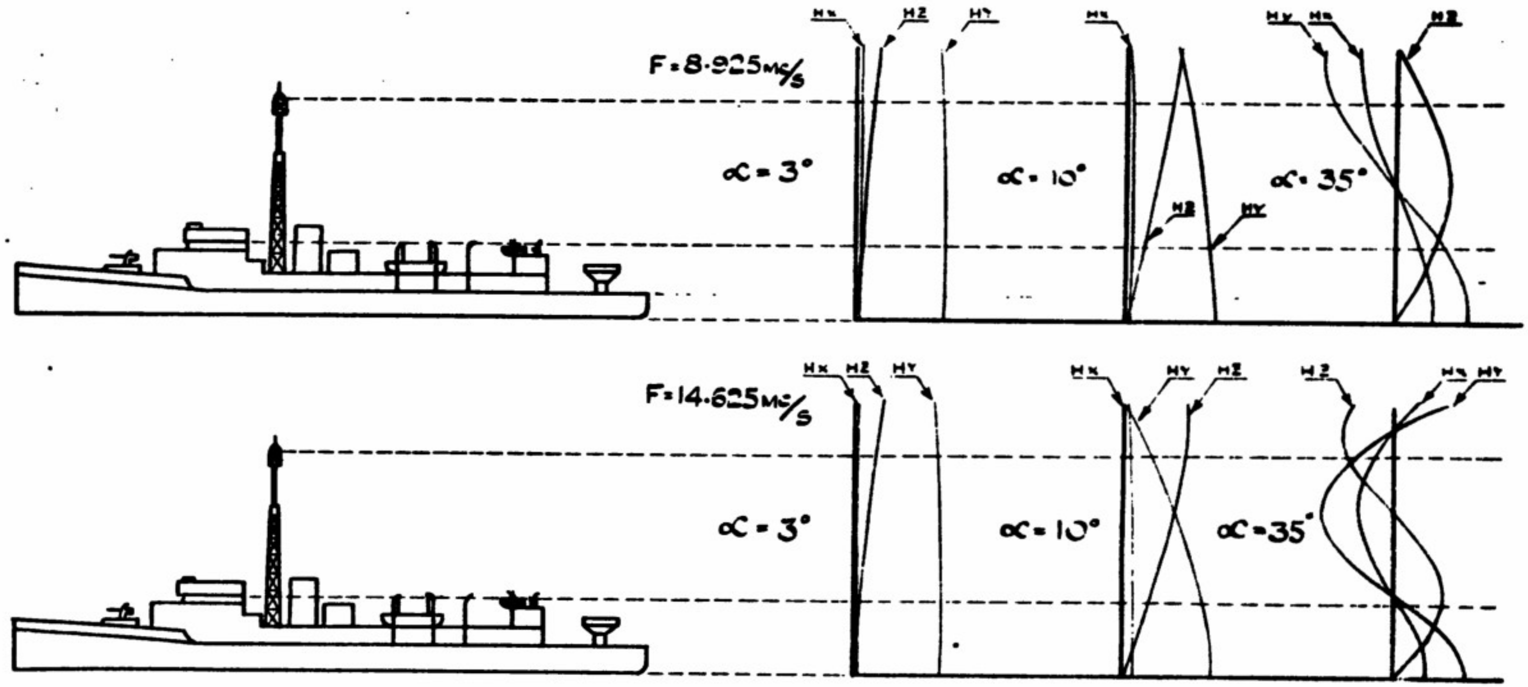


FIG. 7

AIRCRAFT WITH "IDEAL" TRAILING AERIAL

CURVES OF MAXIMUM DEVIATION OF D/F BEARING AS A FUNCTION OF THE ANGULAR ELEVATION OF THE AIRCRAFT NEGLECTING GROUND REFLECTION.
δ = ANGLE OF TRAIL OF AERIAL

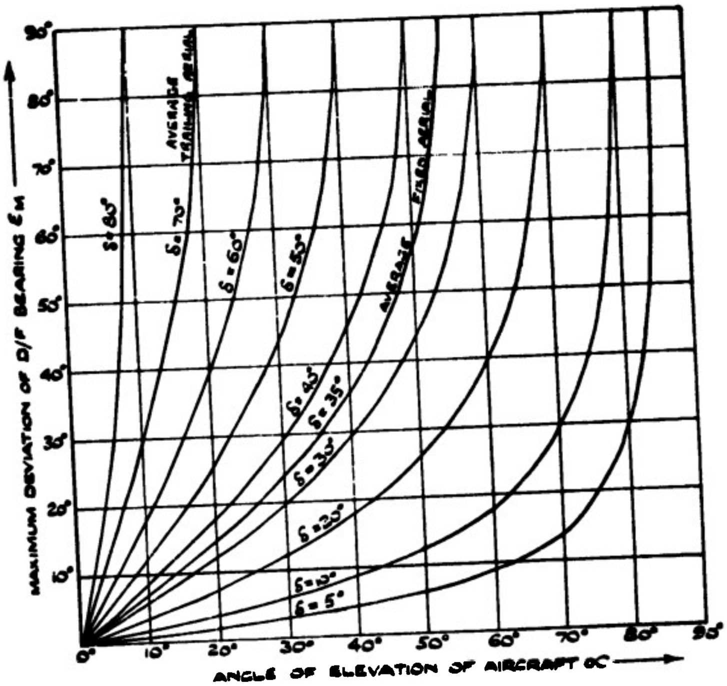


Fig. 8

MAXIMUM DEVIATION $\mathcal{E}_M$ OF D/F BEARING AS A FUNCTION OF THE HORIZONTAL DISTANCE d OF AIRCRAFT FROM THE DIRECTION FINDER FOR VARIOUS ALTITUDES h OF THE AIRCRAFT. ASSUMING AN EQUIVALENT TRAILING AERIAL INCLINED AT 35° TO THE VERTICAL (CORRESPONDING TO THE AVERAGE CASE OF A FIXED AERIAL) AND NEGLECTING GROUND REFLECTION.

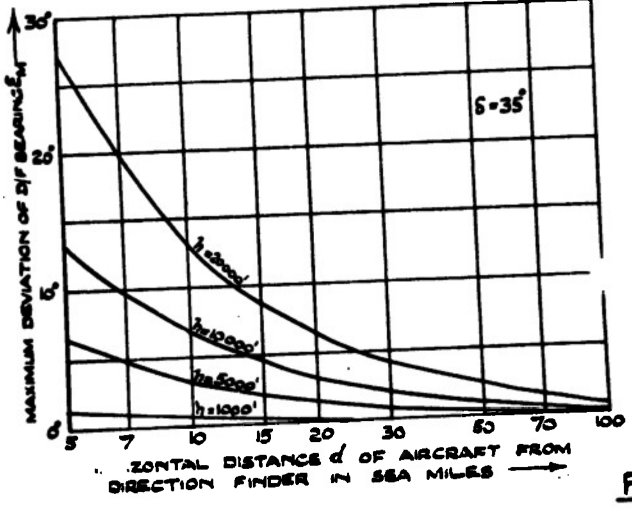


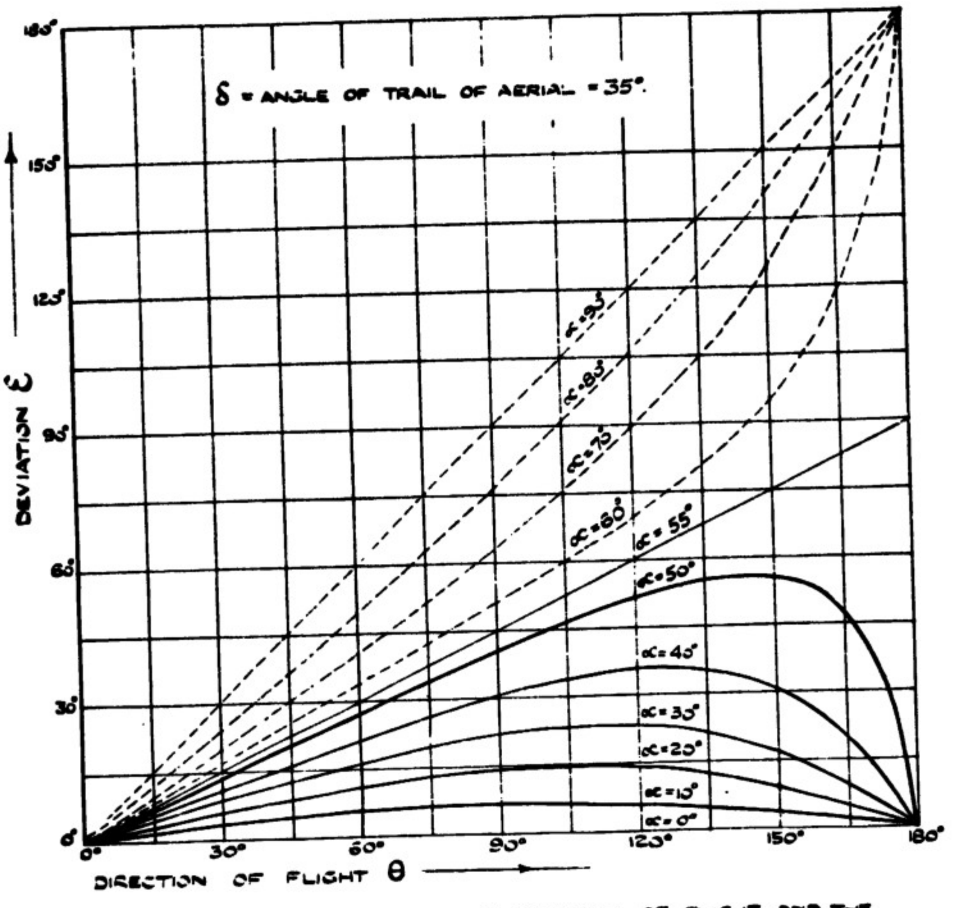
Fig. 9

APR

RALTY SIG AL ESTABLISHMENT DRG Nº

AIRCRAFT WITH 'IDEAL' TRAILING AERIAL

DEVIATION ε IN D/F BEARINGS AS A FUNCTION OF THE DIRECTION OF FLIGHT θ FOR VARIOUS ELEVATIONS α OF THE AIRCRAFT



— θ IS THE ANGLE BETWEEN THE DIRECTION OF FLIGHT AND THE PLANE OF SIGHT —

FIG 10

H.M.S. SALTBURN

SHOWING POSITION OF H/F D/F FRAME COIL S25B

SCALE 1/300 FULL SIZE

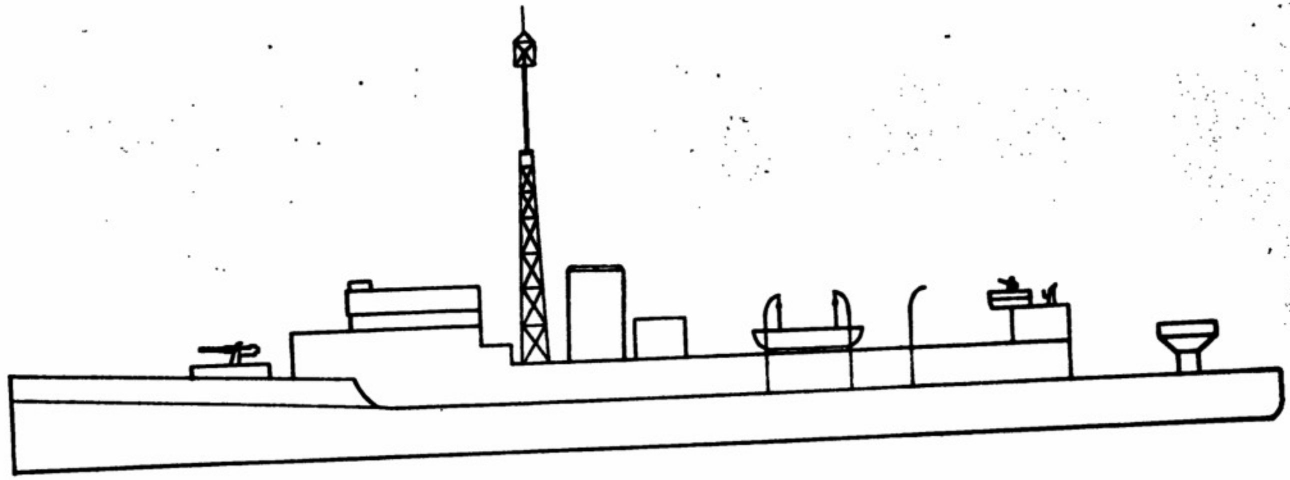


FIG. 11

ADMIRALTY SIGNAL ESTABLISHMENT DRG No

FIXED AND TRAILING H/F TRANSMITTING AERIALS ON FAIREY "FULMAR" AIRCRAFT

Scale One Inch To Six Feet

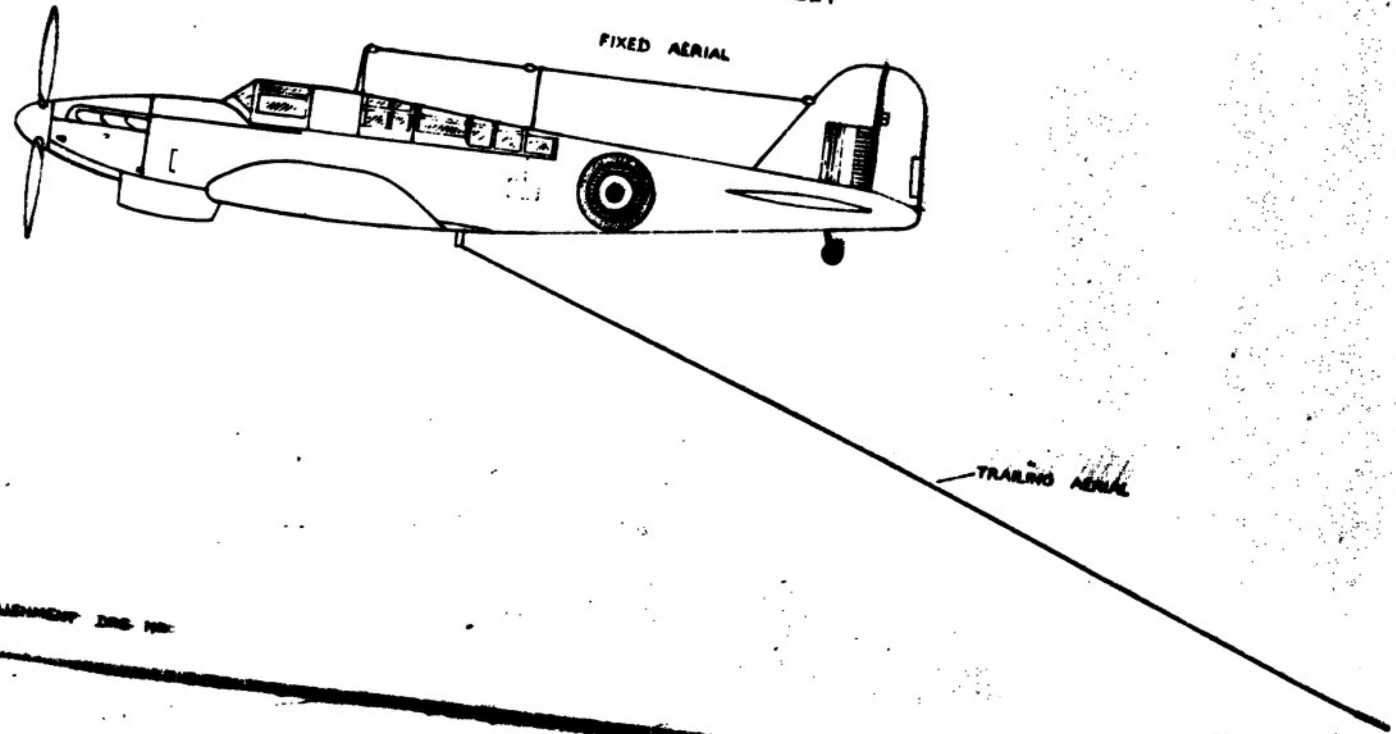


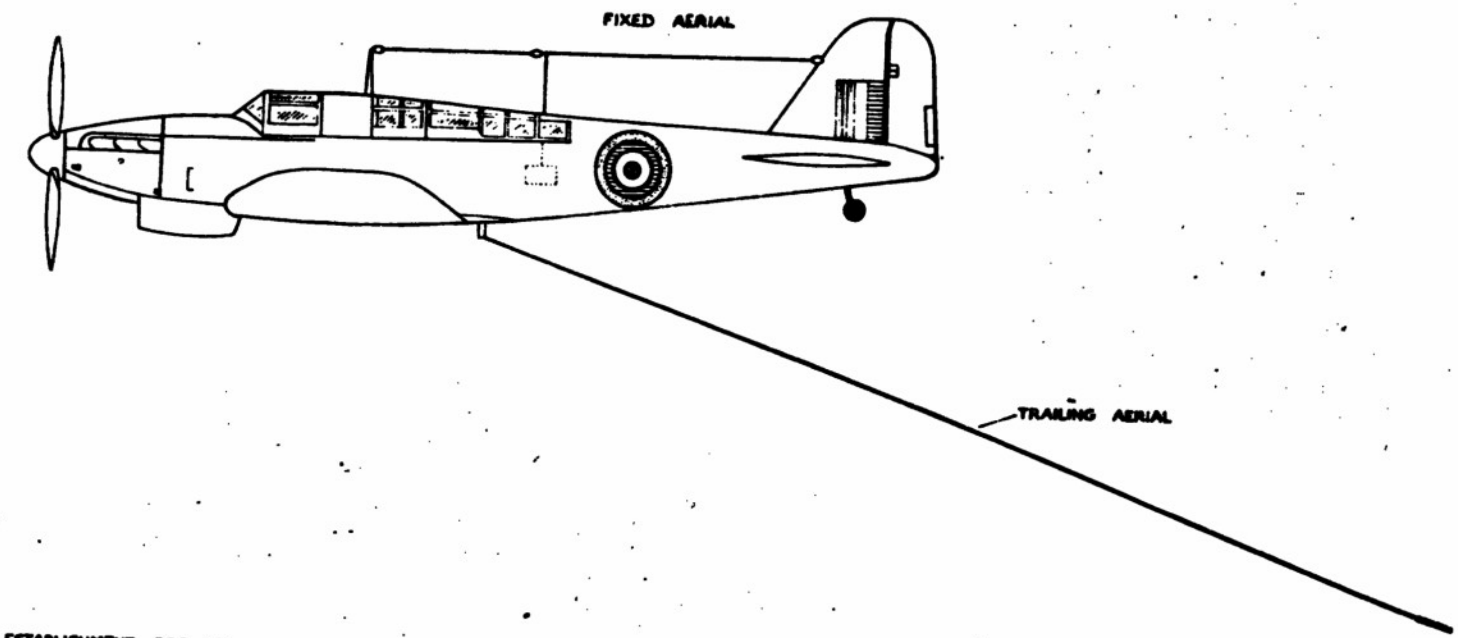
FIG. 12.

ADMIRALTY SIGNAL ESTABLISHMENT DRG. No.

45

FIXED AND TRAILING H/F TRANSMITTING AERIALS ON FAIREY "FULMAR" AIRCRAFT

Scale One Inch To Six Feet

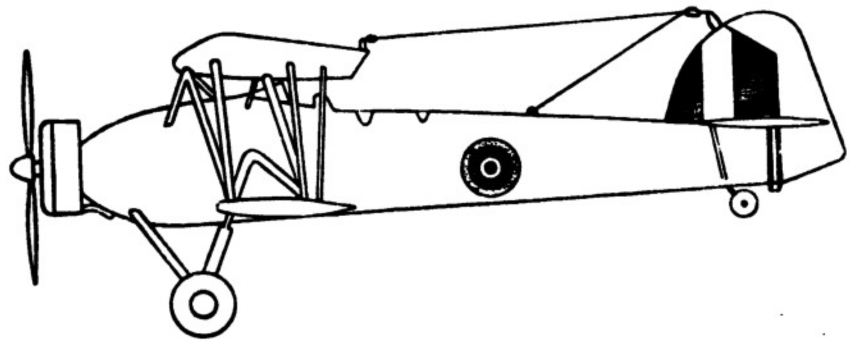


ADMIRALTY SIGNAL ESTABLISHMENT DRG No

FIG. 12.

NORMAL AND SPECIAL FIXED H/F TRANSMITTING AERIALS IN FAIREY "SWORDFISH" AIRCRAFT

Scale One Inch To Six Feet



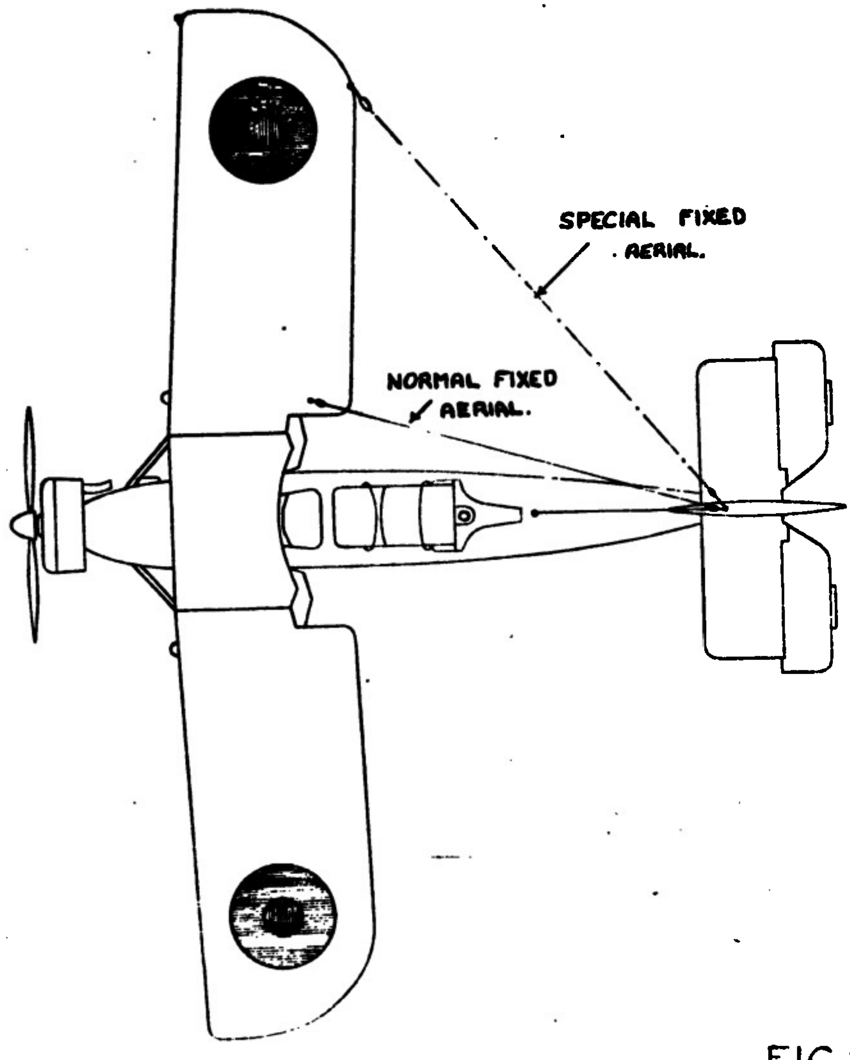


FIG 13

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

REMARKS

TRANSMISSION FROM

FULMAR – TRAILING AERIAL

SPEED 140 KNOTS HEIGHT 3000 FT

ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 10°–14°

CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 4200 Kc/S.

GREEN V/S BEARINGS

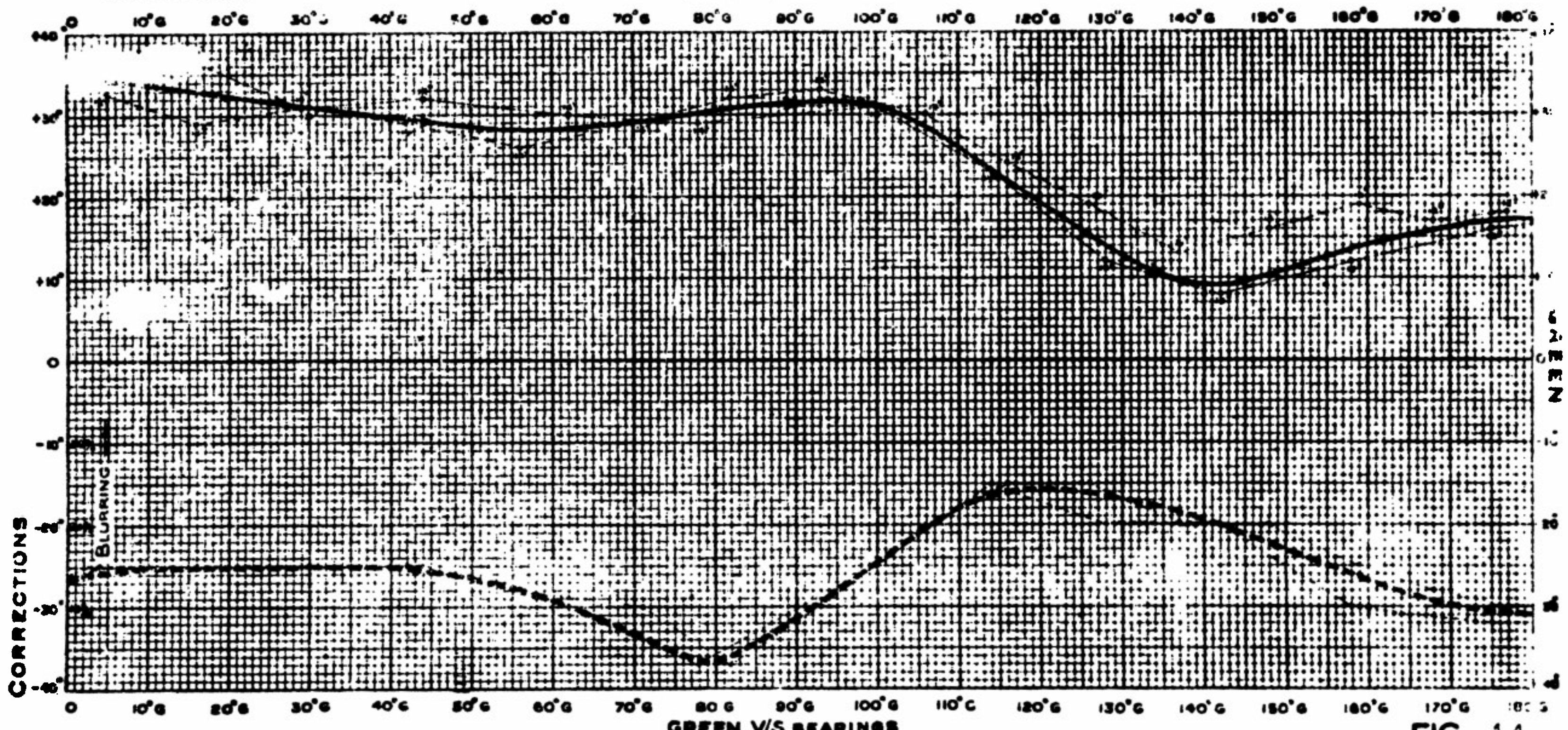


FIG. 14

AL ESTABLISHMENT DRG Nº

51

REMARKS

TRANSMISSION FROM
FULMAR-TRAILING AERIAL
SPEED 140 KNOTS HEIGHT 3000 FT
ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 10°-14°
CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4
H.M.S. SALTBURN
RESULT OF SWING FOR CURVE OF CORRECTION ON 4200 **Kc/S.**
RED V/S BEARINGS

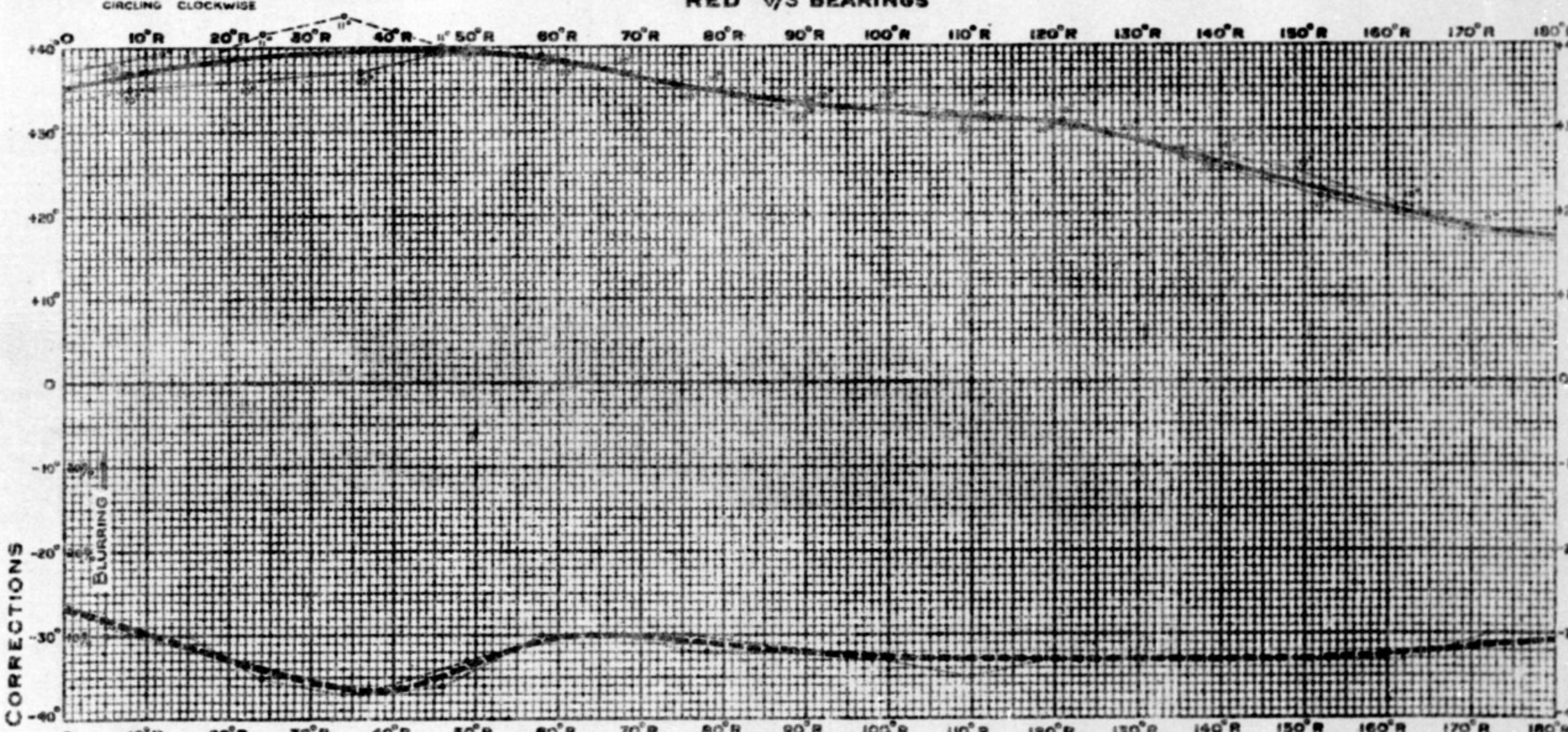


FIG. 15

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

REMARKS

TRANSMISSION FROM

FULMAR – TRAILING AERIAL

SPEED 125 – 160 KNOTS HEIGHT 1000 FT

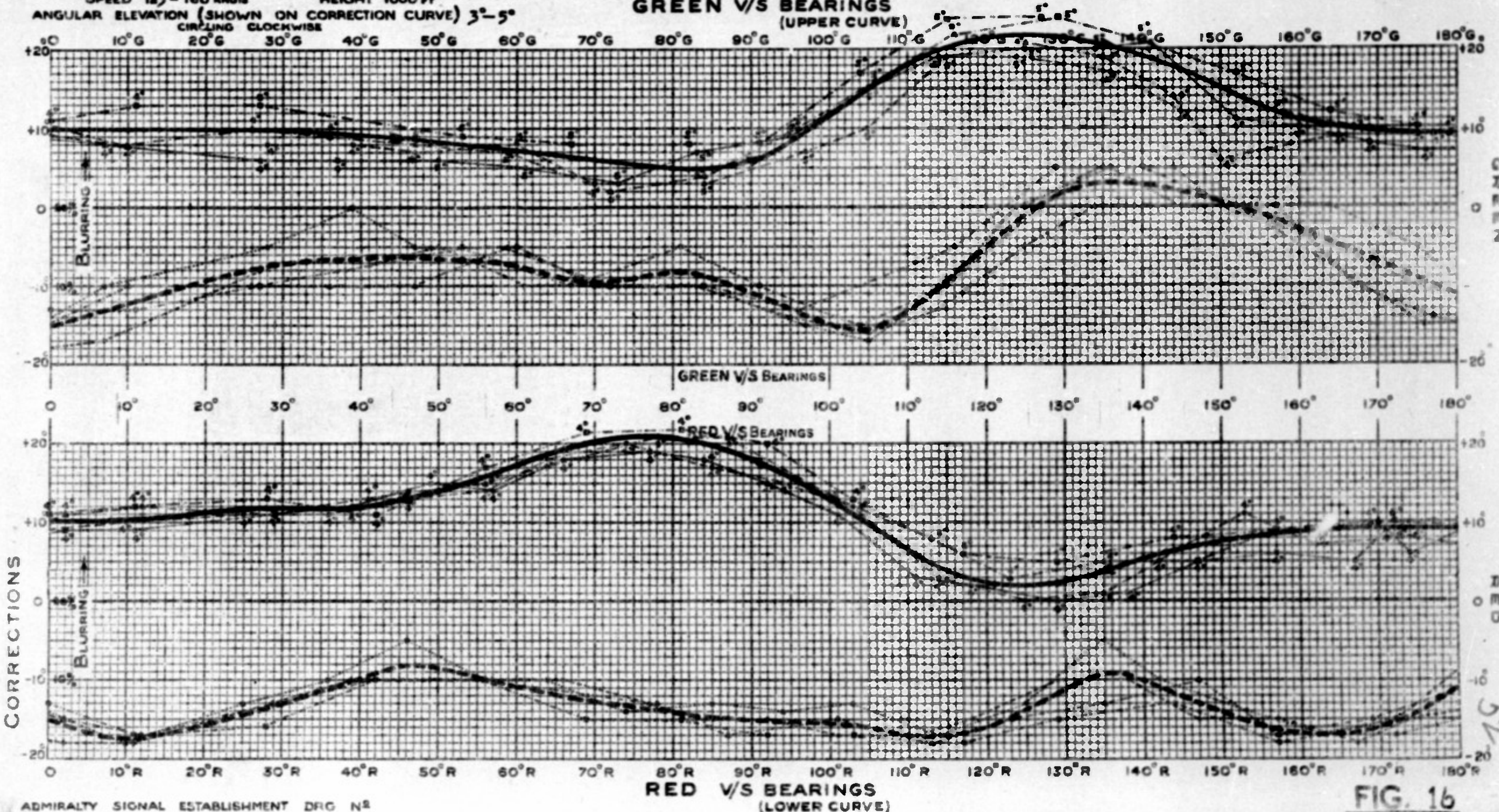
ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 3°–5°

CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 6450 Kc/S.



ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIG. 16

REMARKS

TRANSMISSION FROM

FULMAR—TRAILING AERIAL

SPEED 140 KNOTS HEIGHT 2500–3000 FT

ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 9°–12°

CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 6450 Kc/S

GREEN V/S BEARINGS

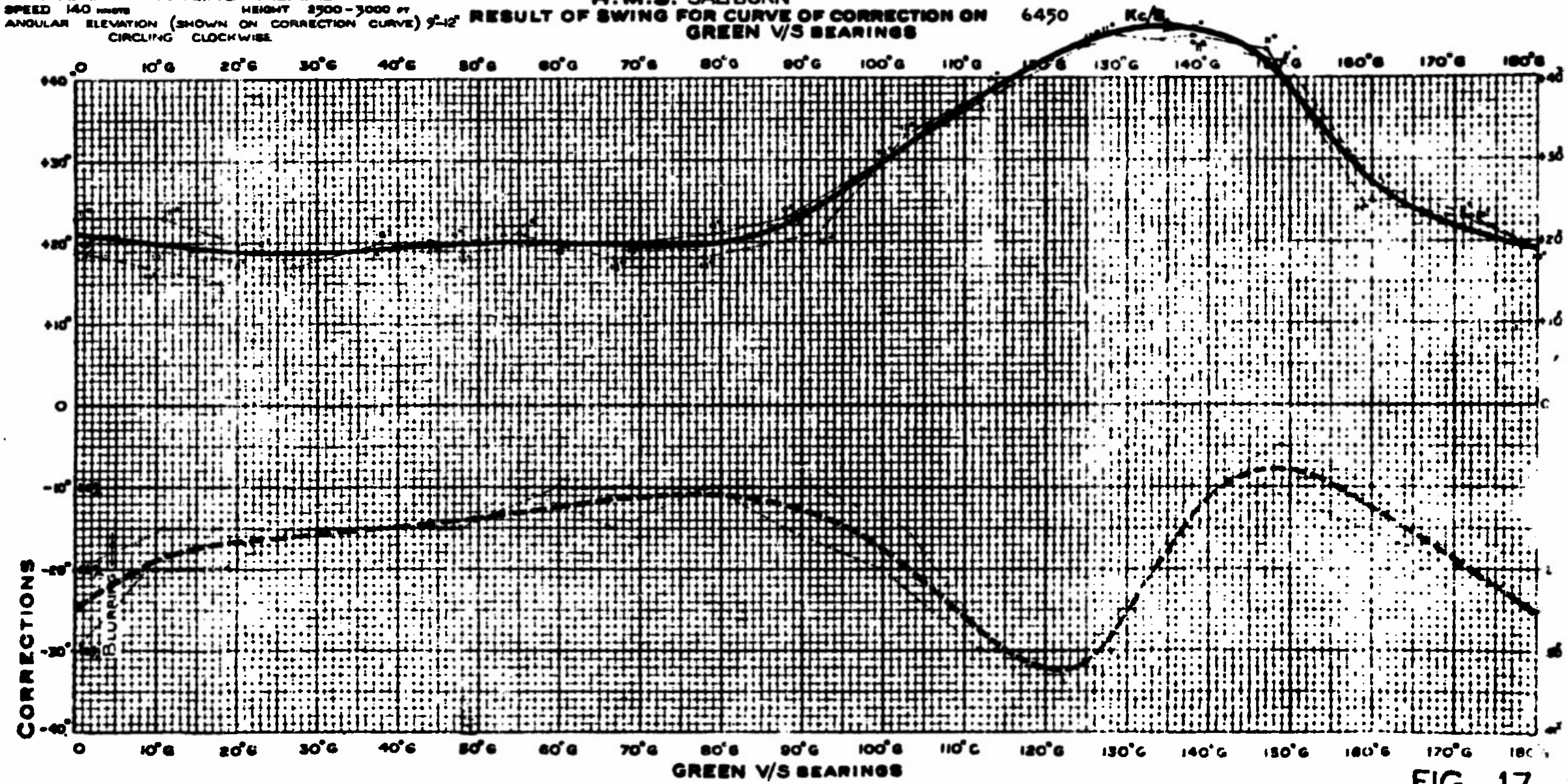


FIG. 17

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

REMARKS

TRANSMISSION FROM

FULMAR – TRAILING AERIAL

SPEED 140 KNOTS HEIGHT 2500 - 3000 FT

ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 9°-12°

CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 6450 **Kc/s.**

RED V/S BEARINGS

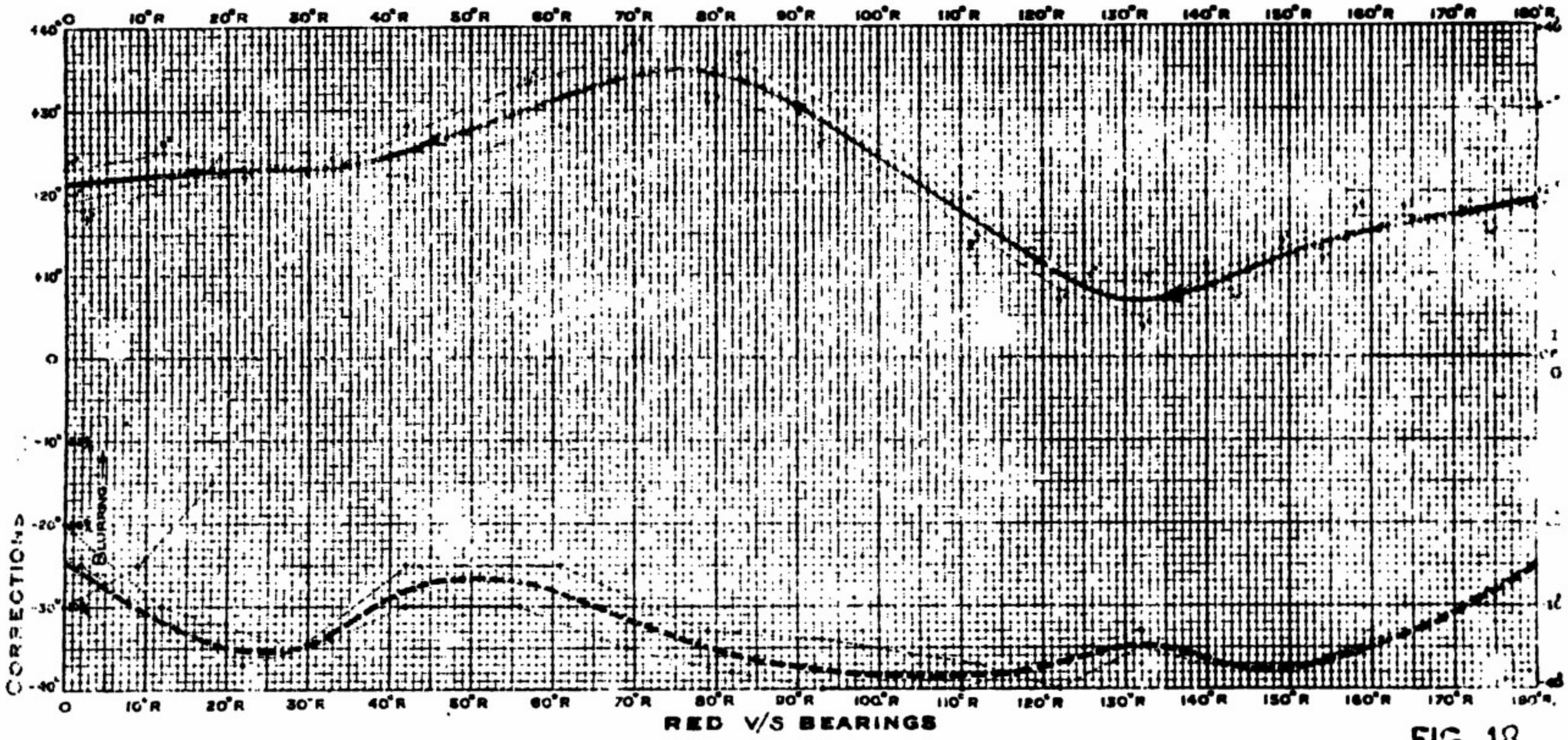


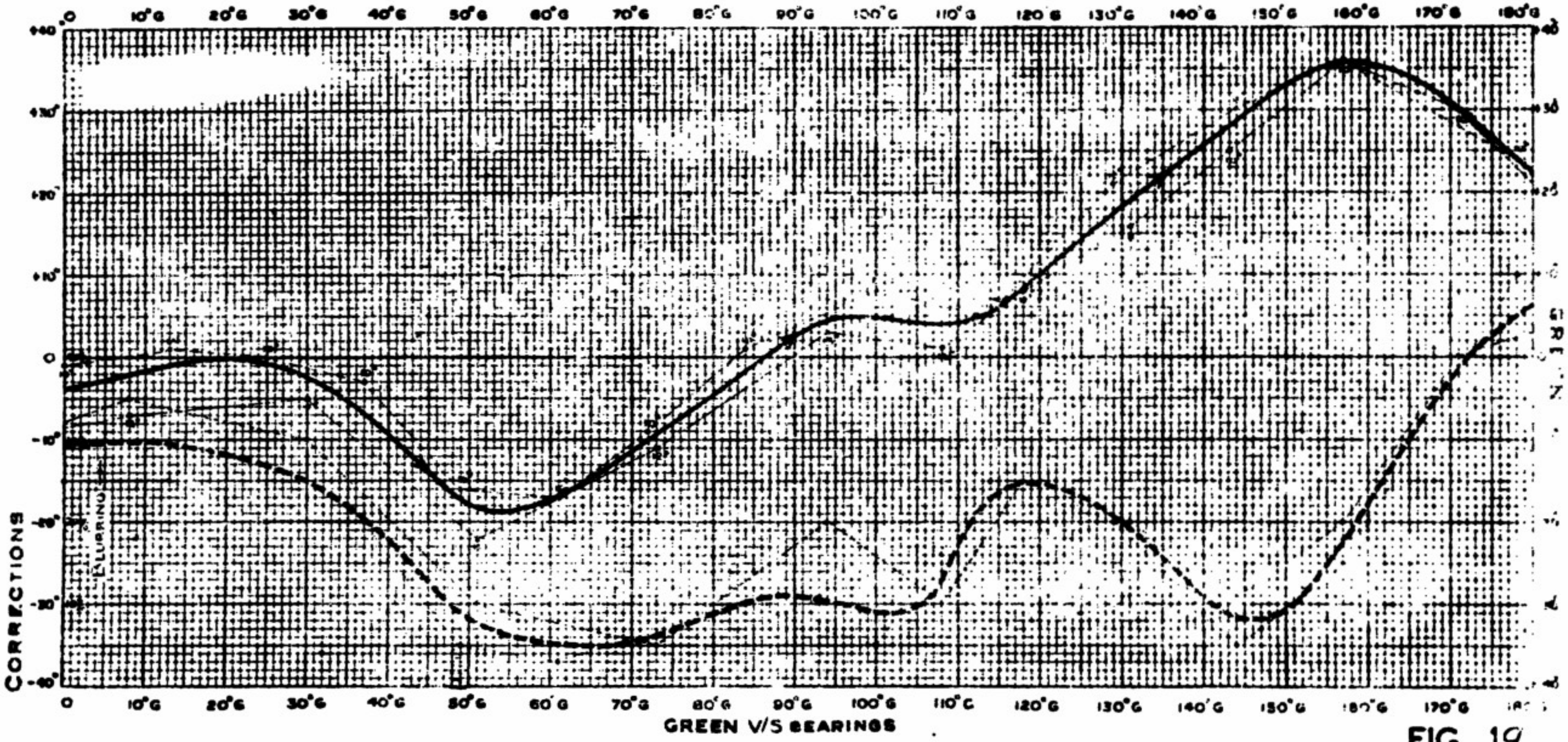
FIG. 18

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

REMARKS

TRANSMISSION FROM
FULMAR – TRAILING AERIAL
SPEED 140 KNOTS HEIGHT 2500 FT
ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 8°–15°
CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4
H.M.S. SALTBURN
RESULT OF SWING FOR CURVE OF CORRECTION ON 8925 Kc/S.
GREEN V/S BEARINGS



ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIG. 19

REMARKS

TRANSMISSION FROM
FULMAR – TRAILING AERIAL
SPEED 140 KNOTS HEIGHT 2500 FT
ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 8°-13°
CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 8925 Kc/s.

RED V/S BEARINGS

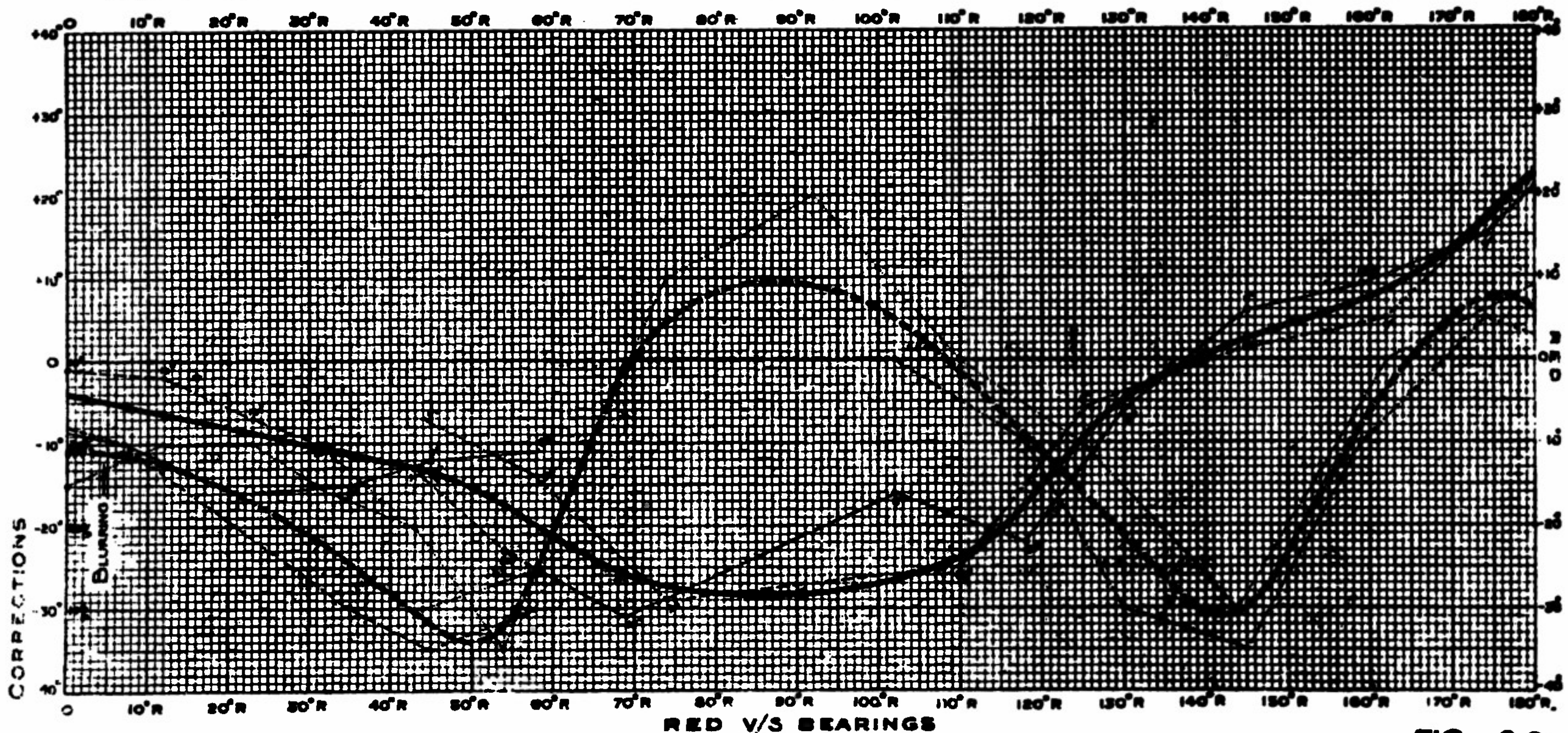


FIG. 20

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

REMARKS

TRANSMISSION FROM FULMAR – TRAILING AERIAL

SPEED 140 KNOTS HEIGHT 2900 FT

ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 8°-12°

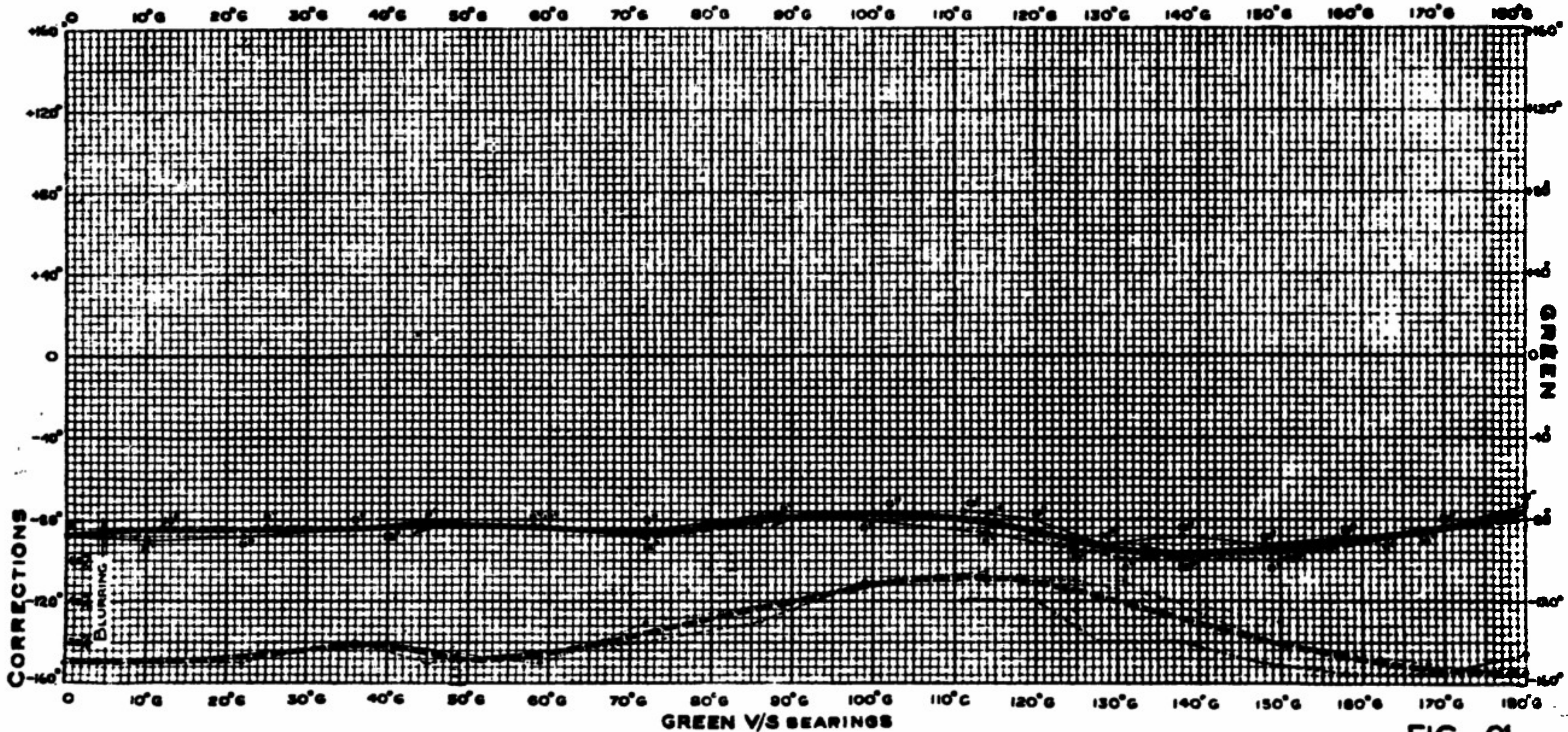
CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 14685 Kc/S.

GREEN V/S BEARINGS



ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIG. 21

REMARKS

TRANSMISSION FROM
FULMAR – TRAILING AERIAL
SPEED 140 KNOTS HEIGHT 2500 FT
ANGULAR ELEVATION (SHOWN ON CORRECTION CURVE) 8°–12°
CIRCLING CLOCKWISE

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 14685 **Kc/S.**

RED V/S BEARINGS

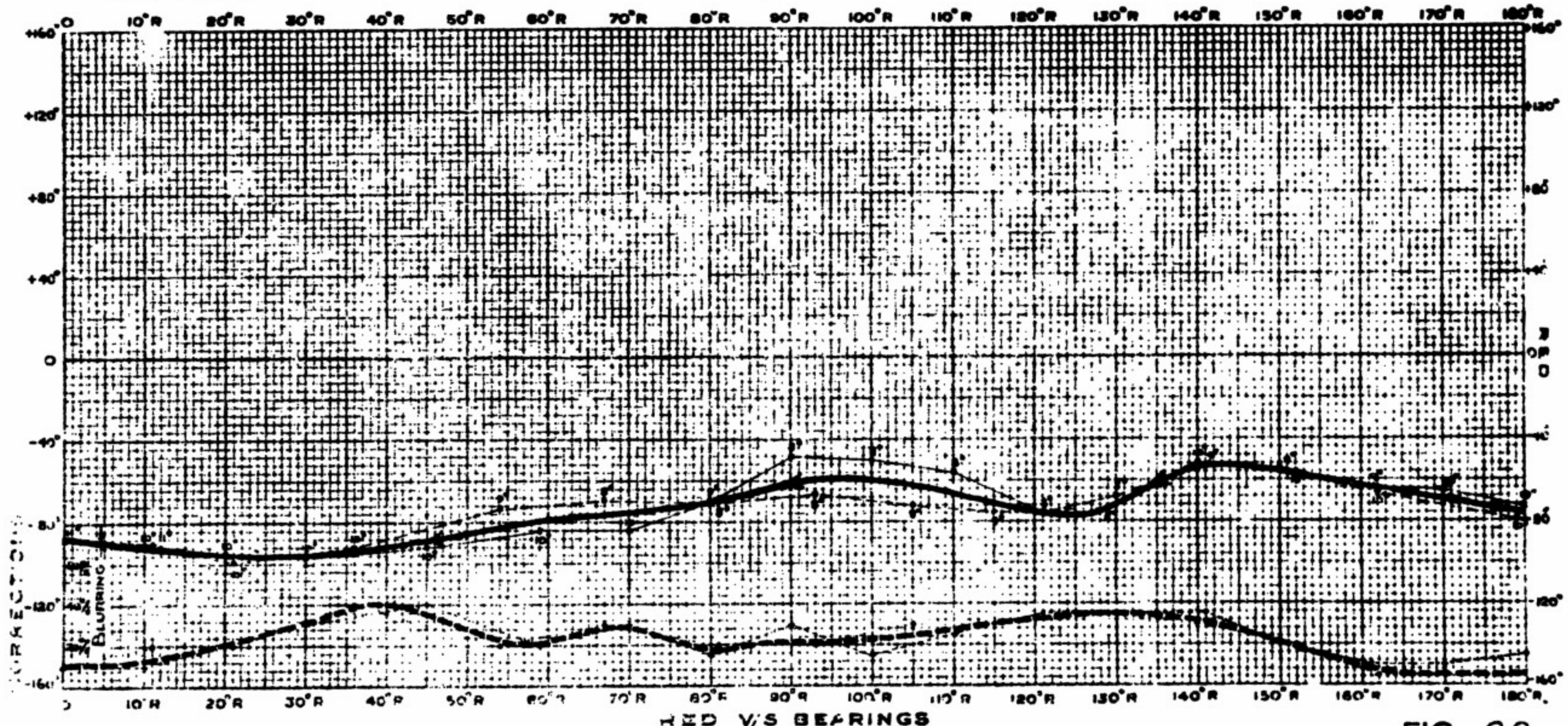


FIG. 22

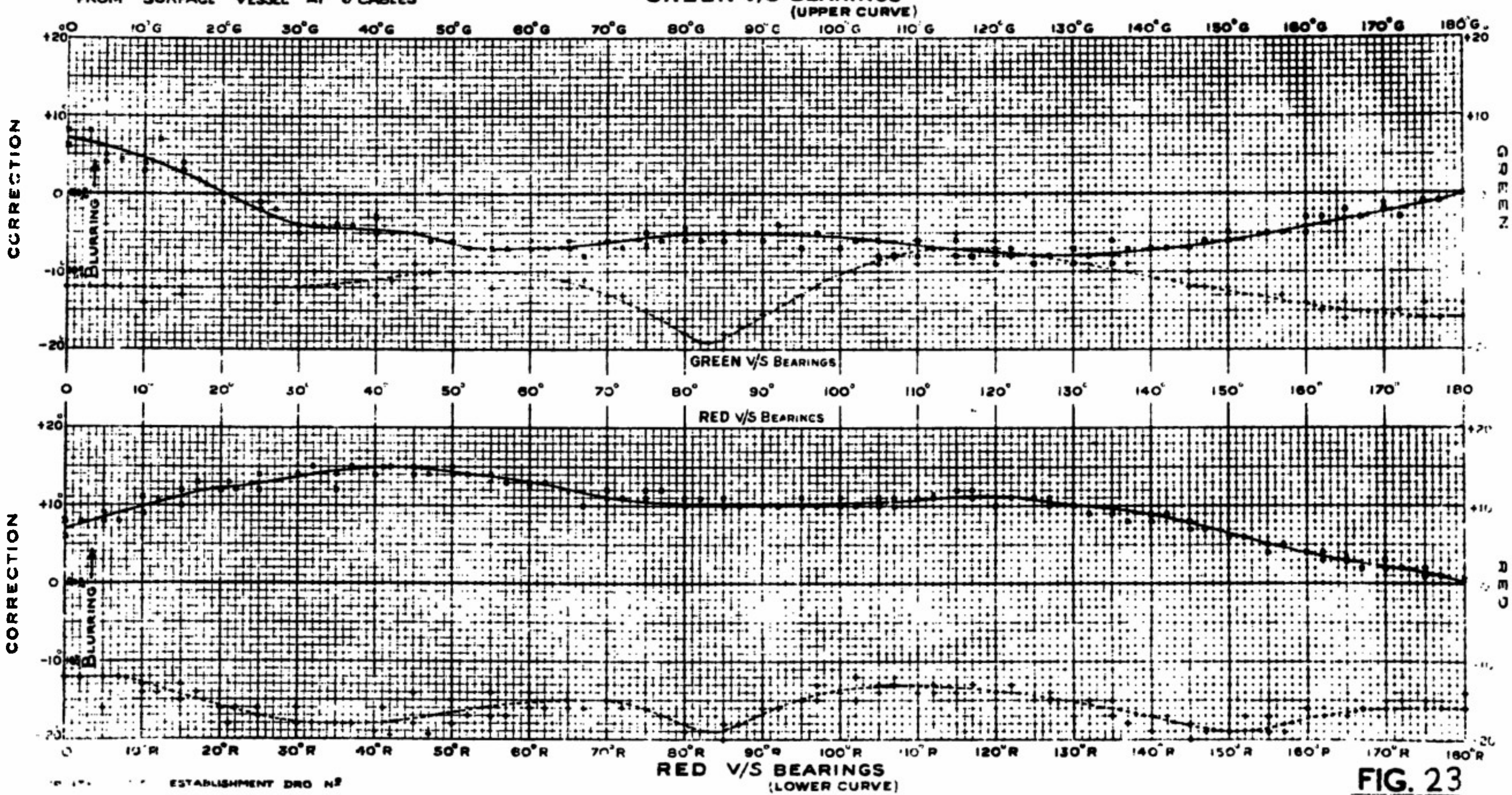
REMARKS

CALIBRATION UPON TRANSMISSION FROM SURFACE VESSEL AT 6 CABLES

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 4200 Kc/S.



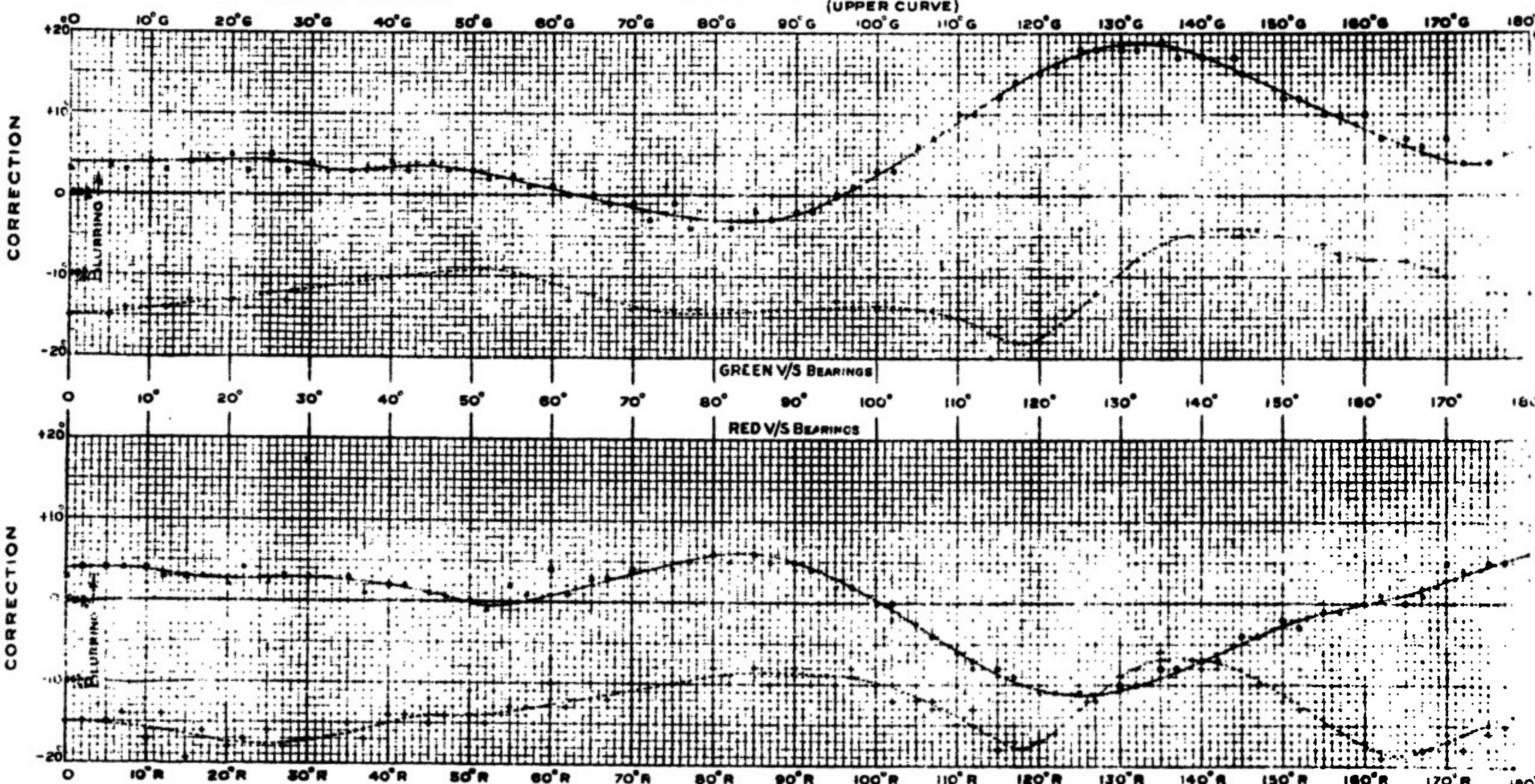
ESTABLISHMENT DRG Nº

FIG. 23

REMARKS

CALIBRATION UPON TRANSMISSION
FROM SURFACE VESSEL AT 6 CABLES

REPORT OF CALIBRATION OF D/F OUTFIT FH4
H.M.S. SALTBURN
RESULT OF SWING FOR CURVE OF CORRECTION ON 6450 Kc/S.
GREEN V/S BEARINGS
(UPPER CURVE)



RED V/S BEARINGS
(LOWER CURVE)

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIG. 24

REMARKS

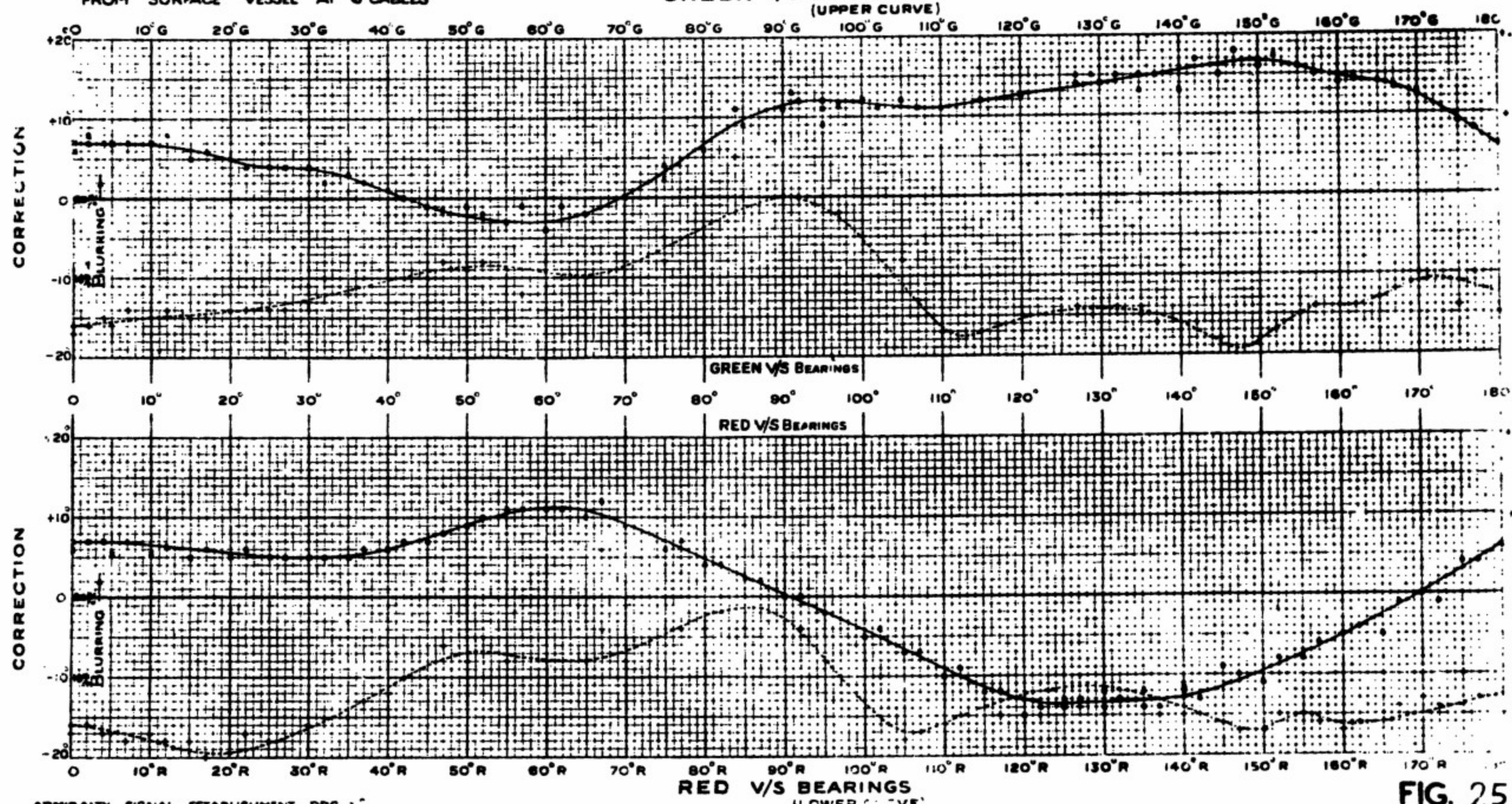
CALIBRATION UPON TRANSMISSION

FROM SURFACE VESSEL AT 6 CABLES

REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 8925 Kc/S.



ADMIRALTY SIGNAL ESTABLISHMENT

FIG. 25

REMARKS

CALIBRATION UPON TRANSMISSION

FROM SURFACE VESSEL AT 6 CABLES

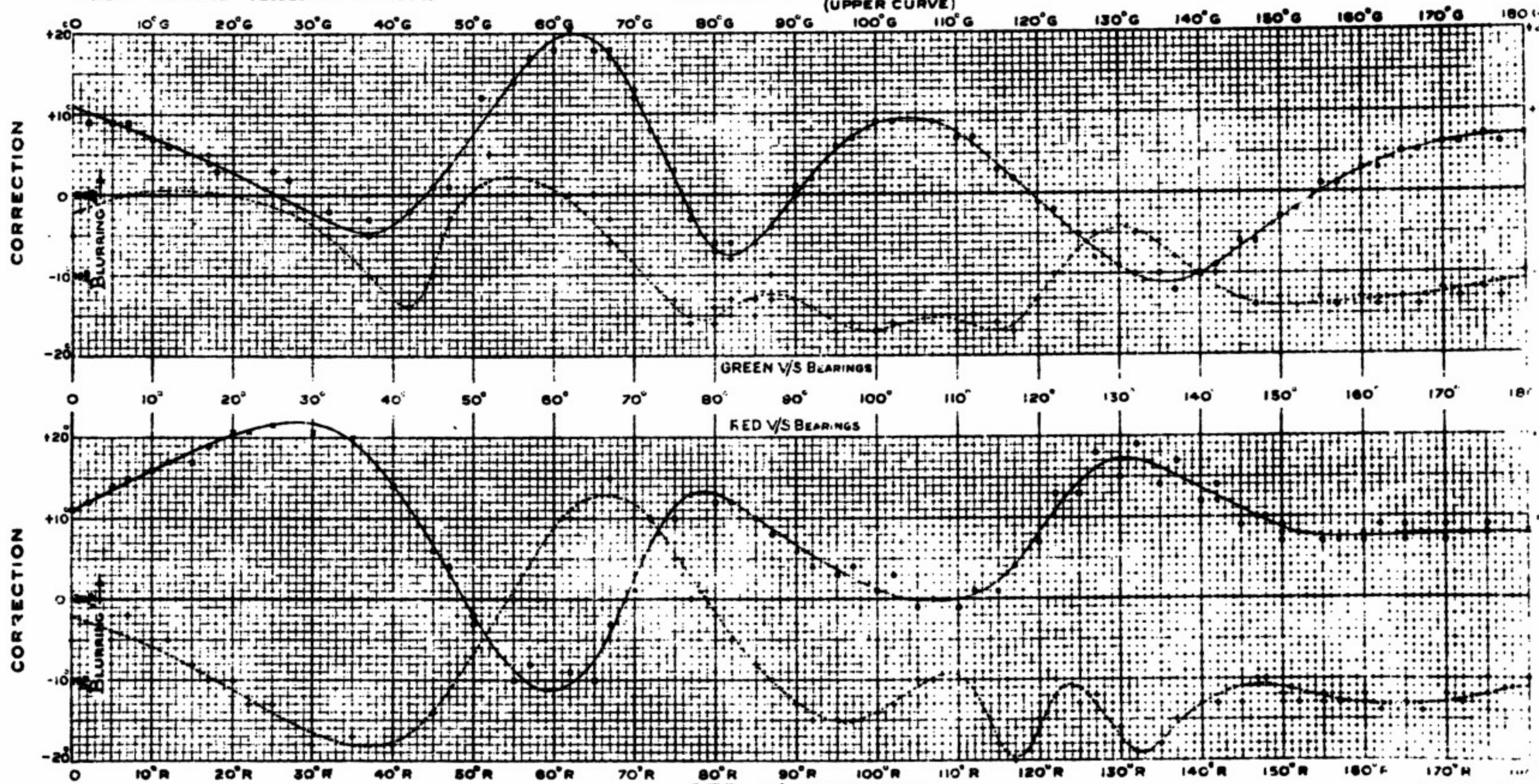
REPORT OF CALIBRATION OF D/F OUTFIT FH4

H.M.S. SALTBURN

RESULT OF SWING FOR CURVE OF CORRECTION ON 14685 Kc/S.

GREEN V/S BEARINGS

(UPPER CURVE)



RED V/S BEARINGS

(LOWER CURVE)

ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIG 26

63-

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT FH.4 IN H.M.S. SALTBURN CORRECTION CURVES

FULMAR - TRAILING AERIAL FREQUENCY 4·2MC/S

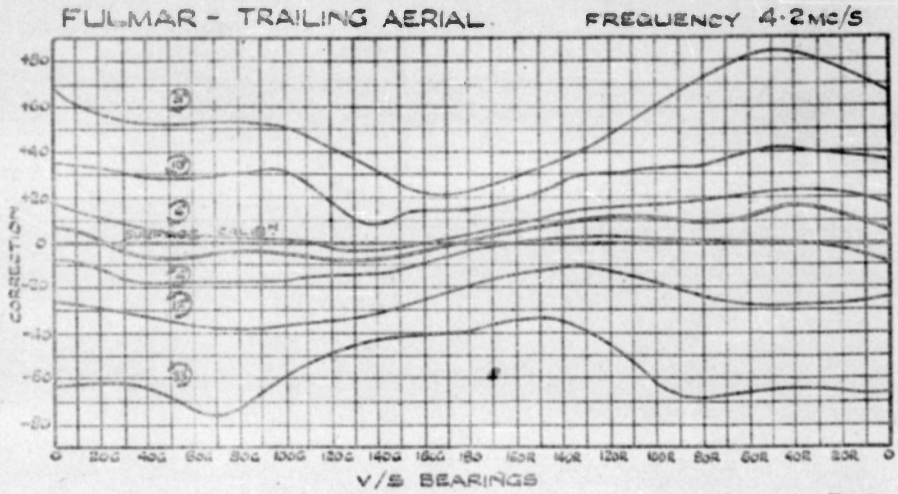


FIG.27

FULMAR - FIXED AERIAL

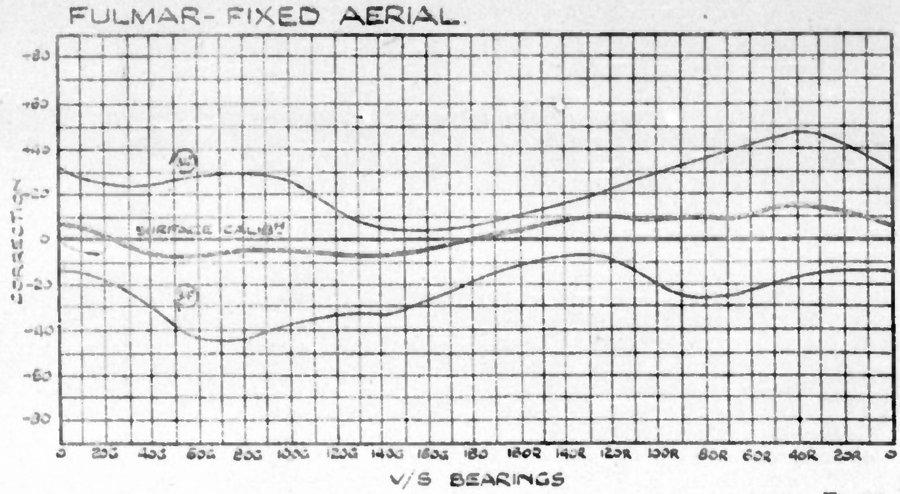


FIG.28

SWORDFISH - FIXED AERIAL

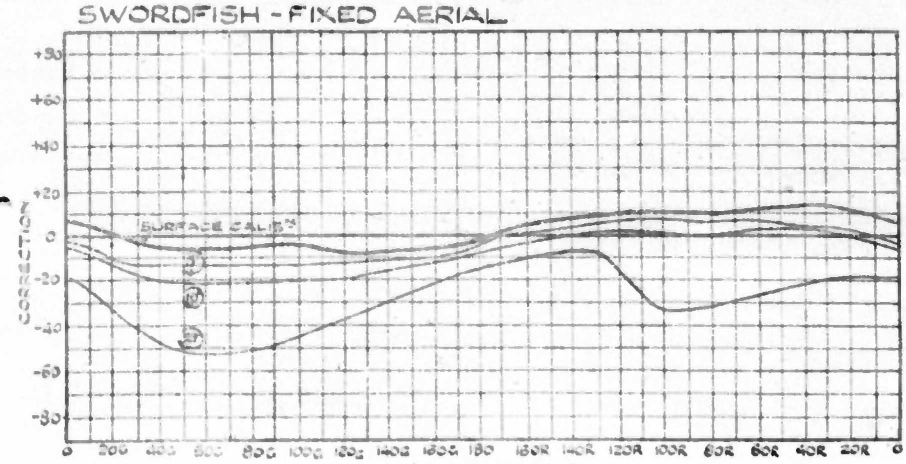


FIG.29

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT F.H.4 IN H.M.S SALTBURN. CORRECTION CURVES.

FULMAR - TRAILING AERIAL FREQUENCY 6·45 MC/S

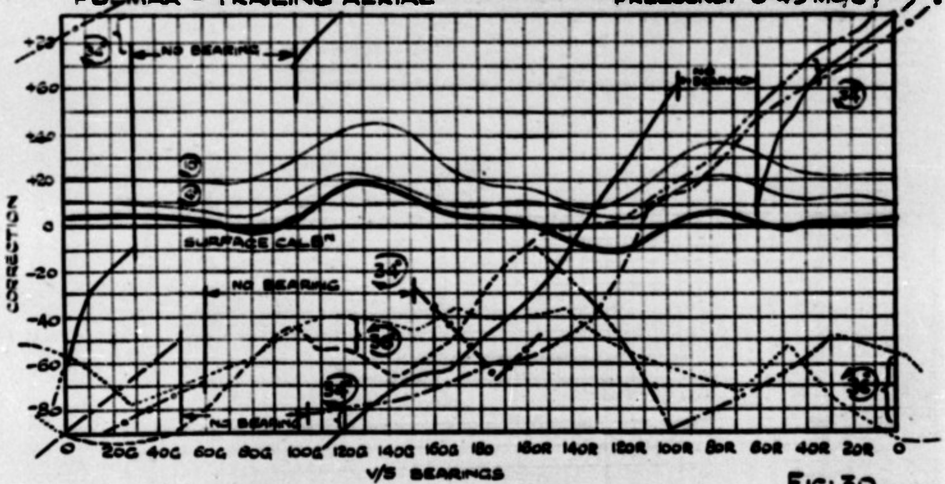


FIG: 30

FULMAR - FIXED AERIAL

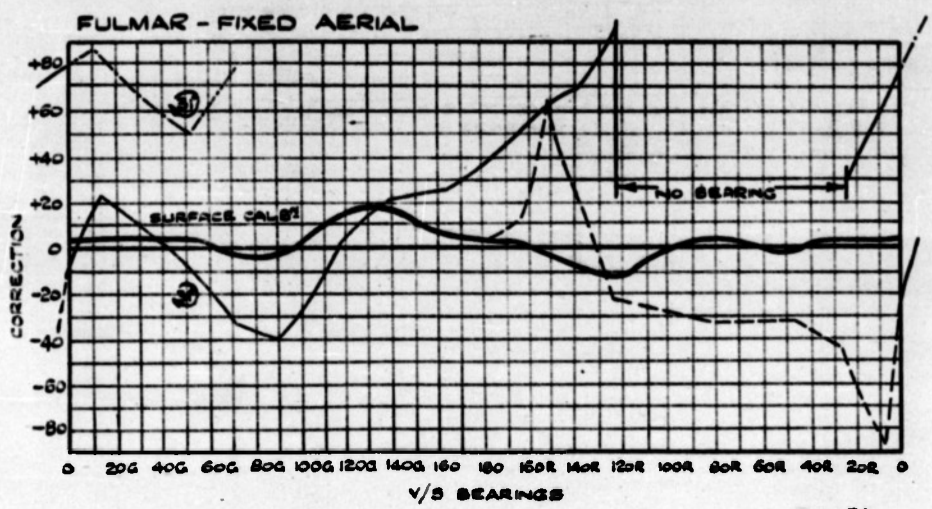


FIG: 31

SWORDFISH - FIXED AERIAL

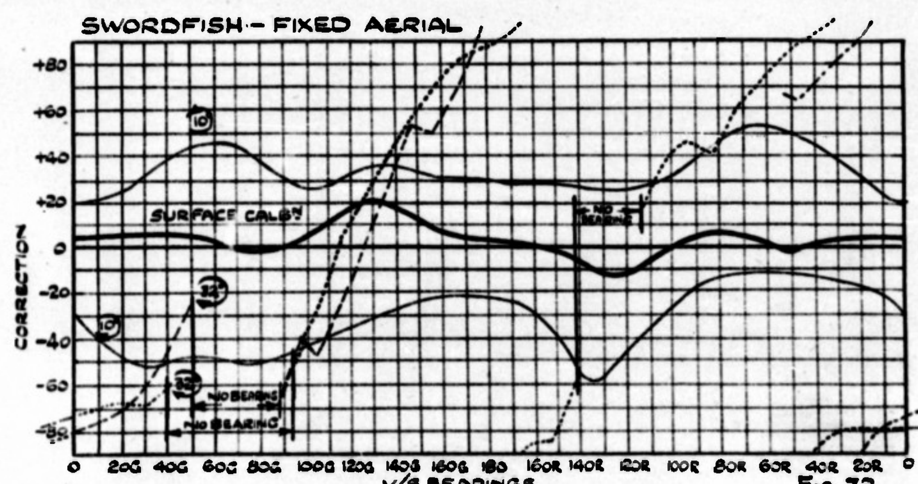


FIG. 32

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT FH4.
IN H.M.S. SALTBURN

CORRECTION CURVES.

FULMAR – TRAILING AERIAL

FREQUENCY 5.925 MC/S

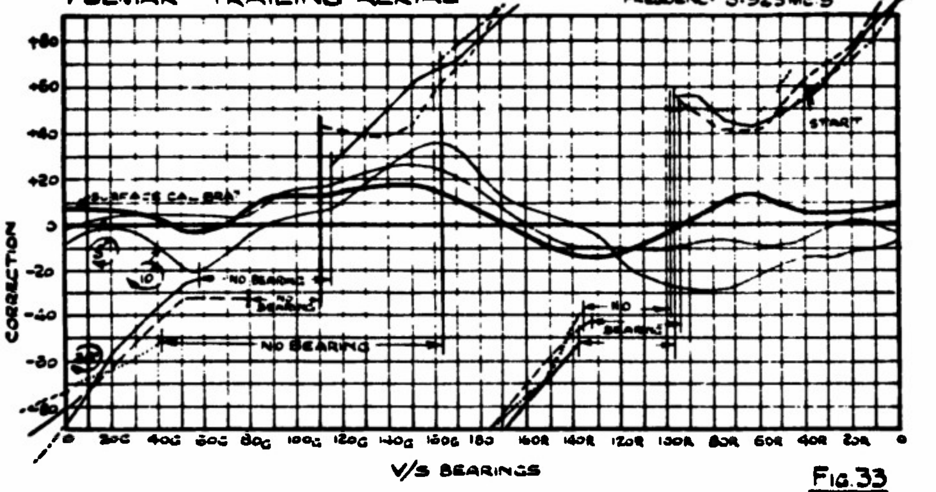


FIG. 33

FULMAR – FIXED AERIAL

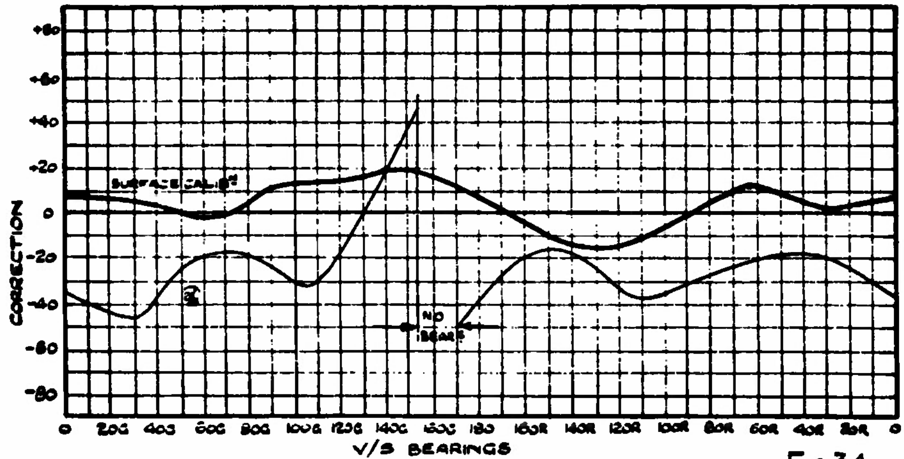


FIG. 34

SWORDFISH – FIXED AERIAL

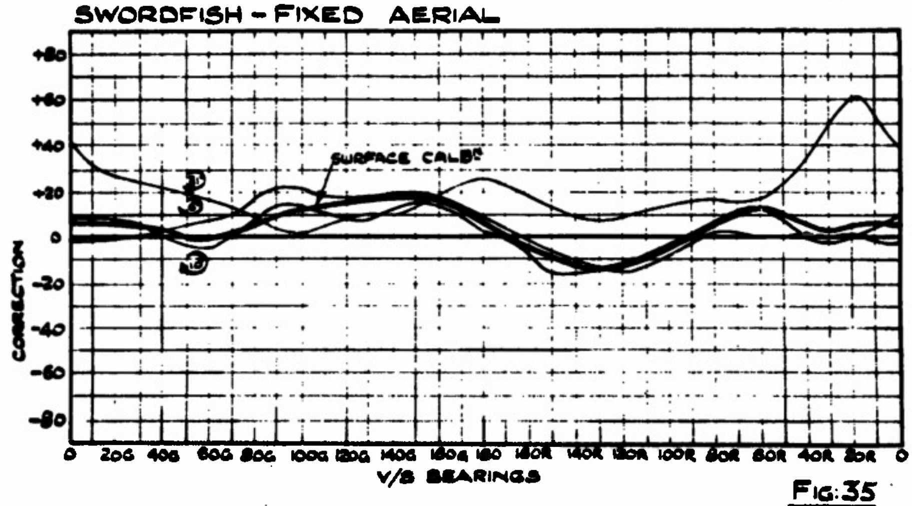


FIG. 35

66-

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT FH4

IN H.M.S SALTBURN

FREQUENCY 14·685 MC/S

CORRECTION CURVES

FULMAR - TRAILING AERIAL

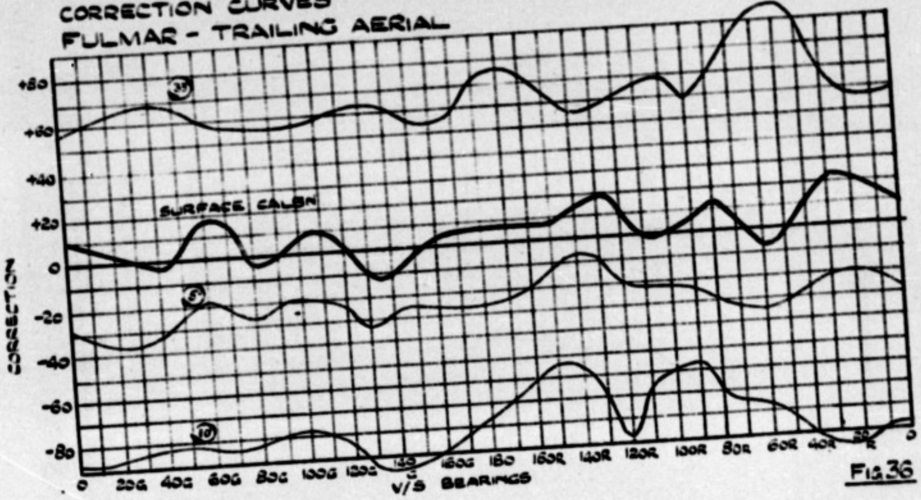


Fig.36

FULMAR - FIXED AERIAL

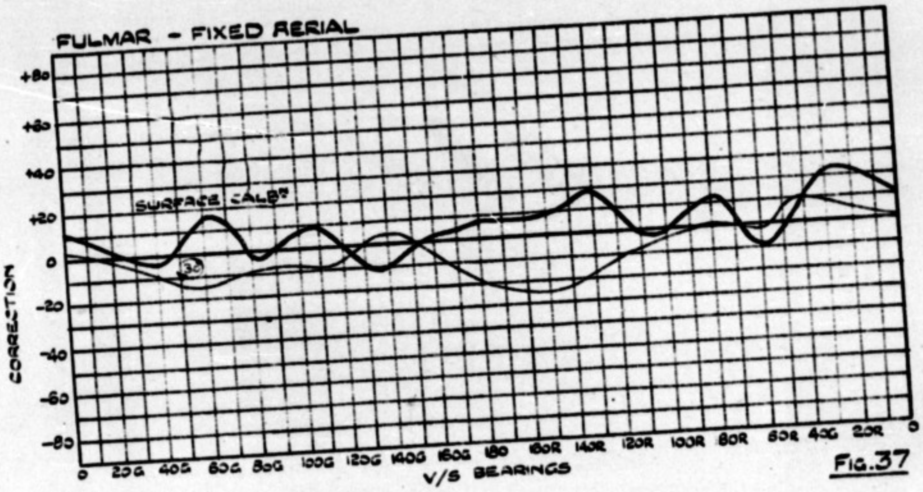


Fig.37

SWORDFISH - FIXED AERIAL

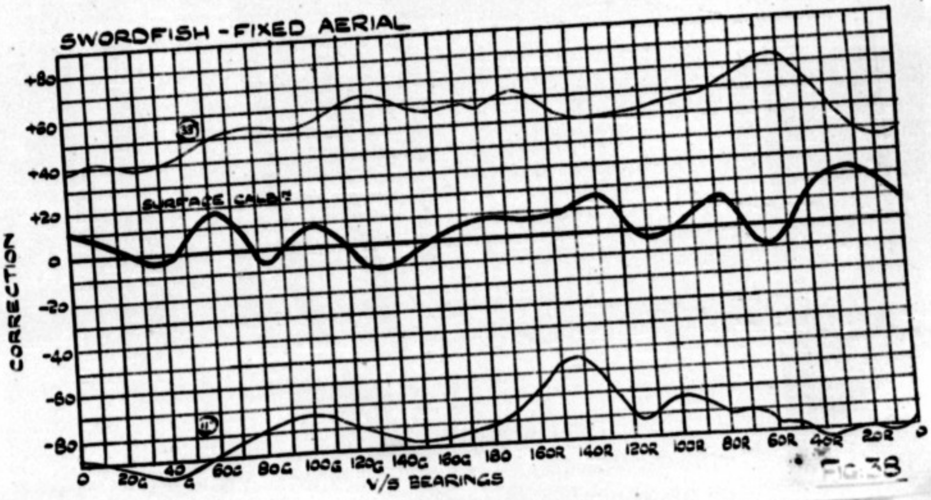


Fig.38

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT FH4 IN H.M.S.SALTBURN

BLURRING CURVES **FREQUENCY 4·2 Mc/s**

FULMAR–TRAILING AERIAL

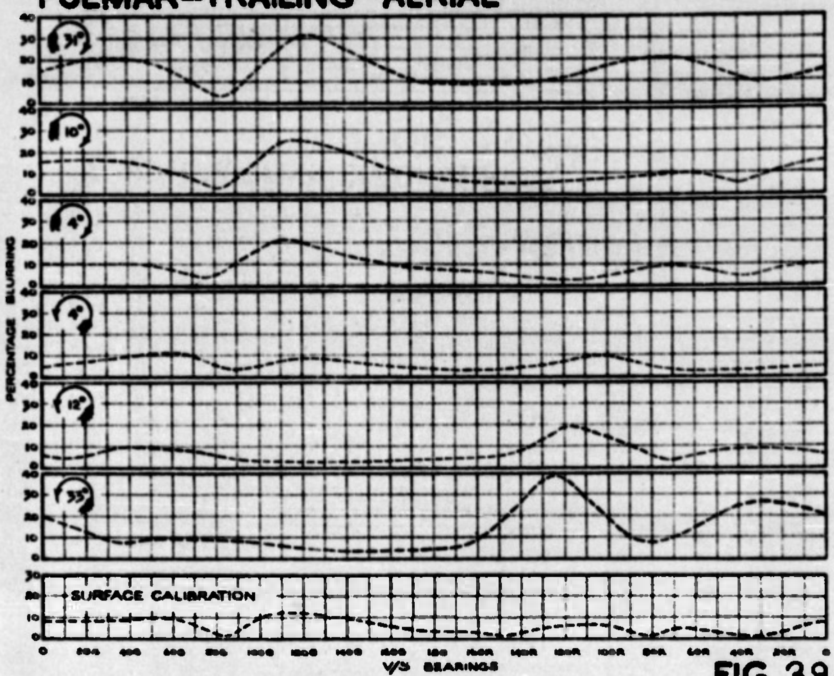


FIG. 39

FULMAR–FIXED AERIAL

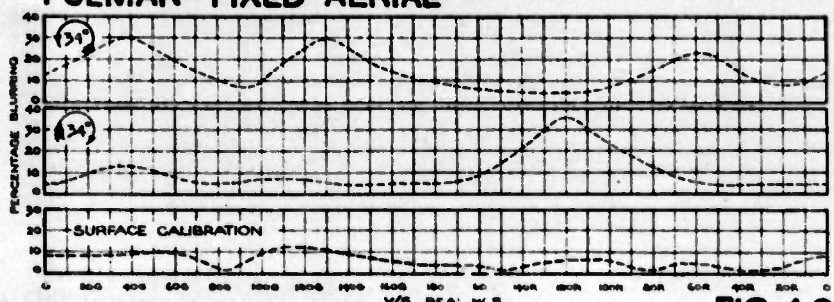


FIG. 40

SWORDFISH–FIXED AERIAL

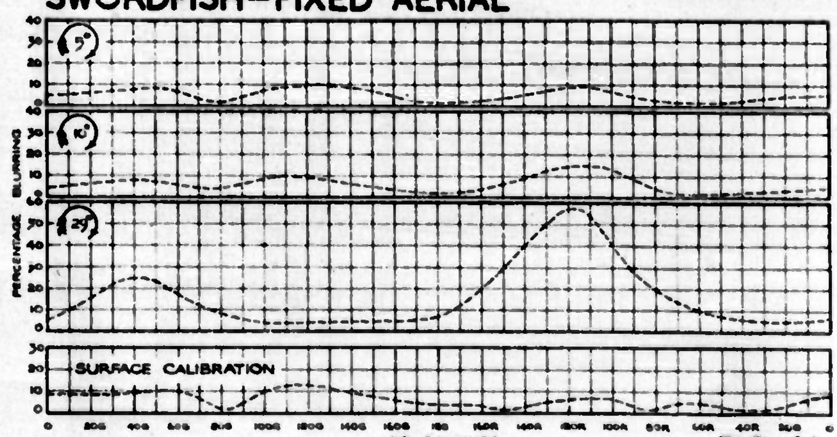


FIG. 41

7

AIRCRAFT CALIBRATION OF H/F D.F. OUTPUT FH4
IN H.M.S. SALTBURN

BLURRING CURVES FREQUENCY 6·45MC/S

FULMAR - TRAILING AERIAL

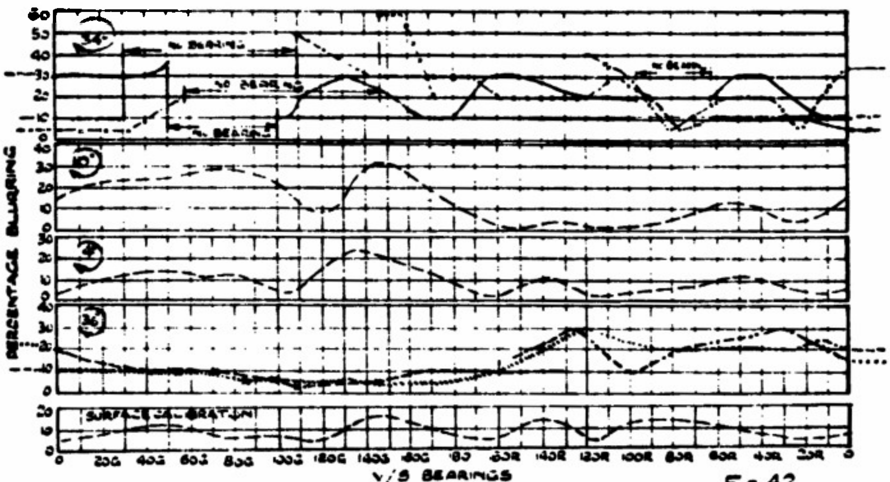


Fig. 42

FULMAR - FIXED AERIAL

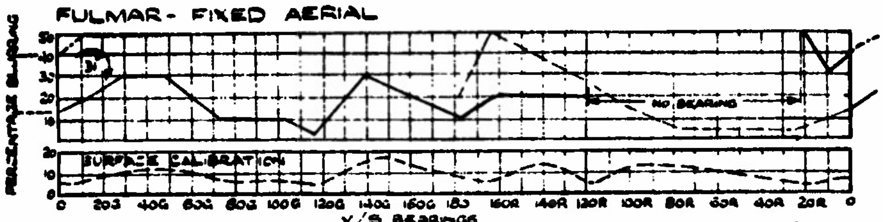


Fig. 43

SWORDFISH - FIXED AERIAL

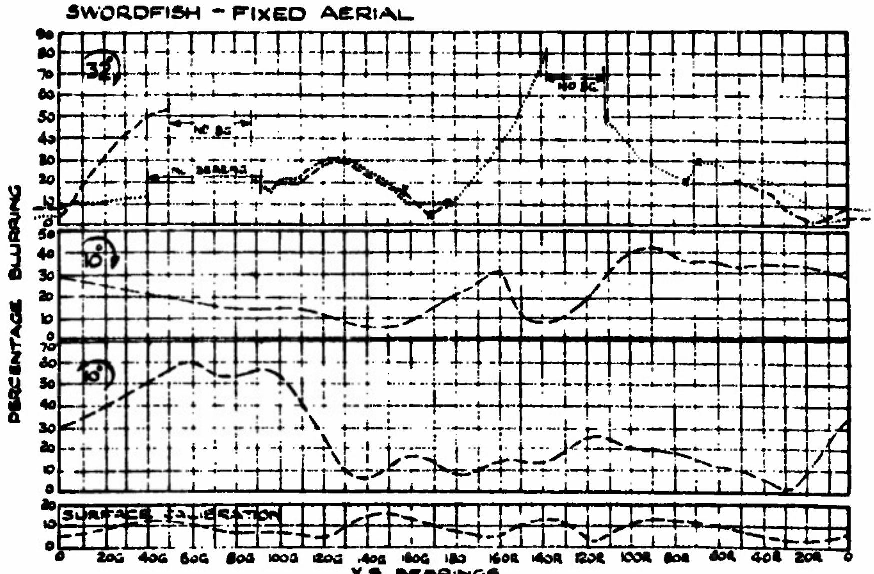


Fig 44

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT F.H.4 IN H.M.S. SALTBURN.

BLURRING CURVES

FREQUENCY 8·927 Mc/s

FULMAR - TRAILING AERIAL

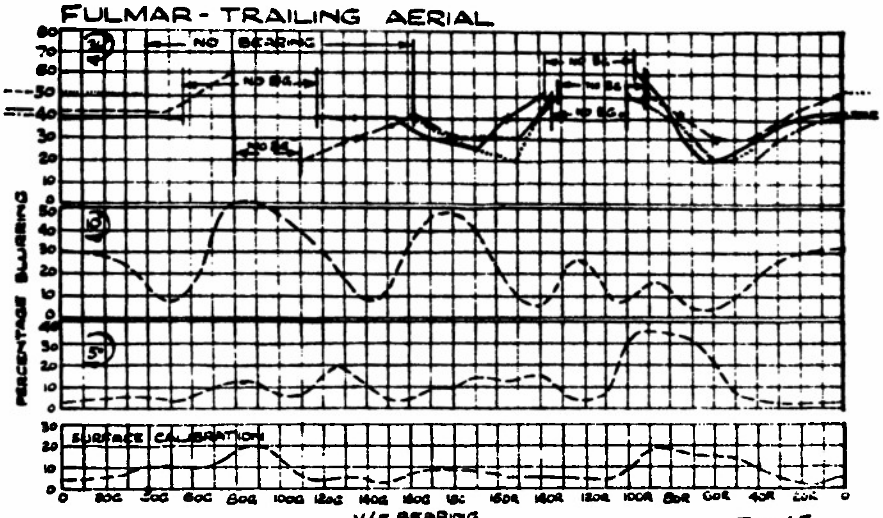


FIG 45

FULMAR - FIXED AERIAL

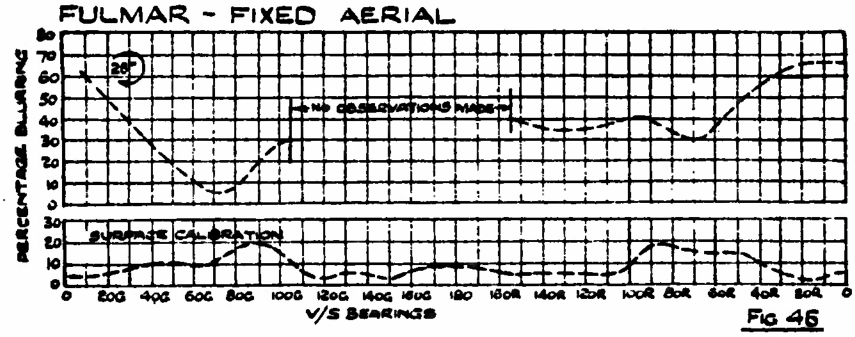


FIG 46

SWORDFISH - FIXED AERIAL

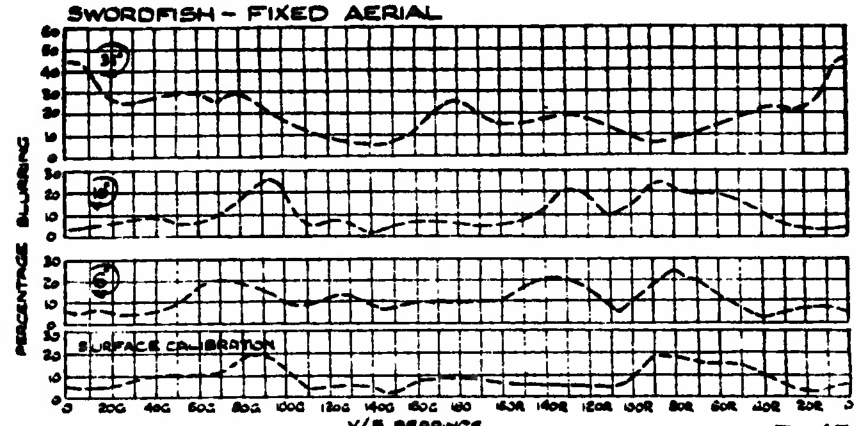


FIG. 47

AIRCRAFT CALIBRATION OF H/F D/F OUTFIT FH4 IN H.M.S.SALTBURN

BLURRING CURVES FREQUENCY 14·685 Mc/s

FULMAR–TRAILING AERIAL

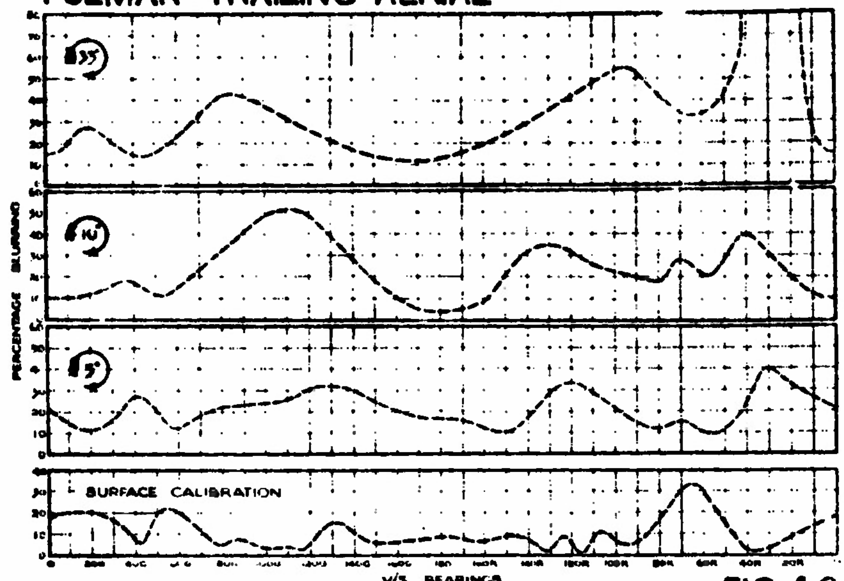


FIG. 48

FULMAR–FIXED AERIAL

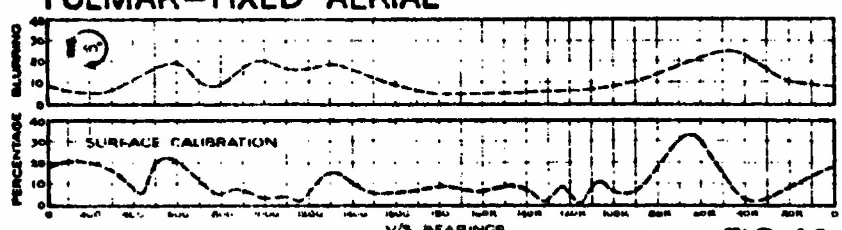


FIG. 49

SWORDFISH–FIXED AERIAL

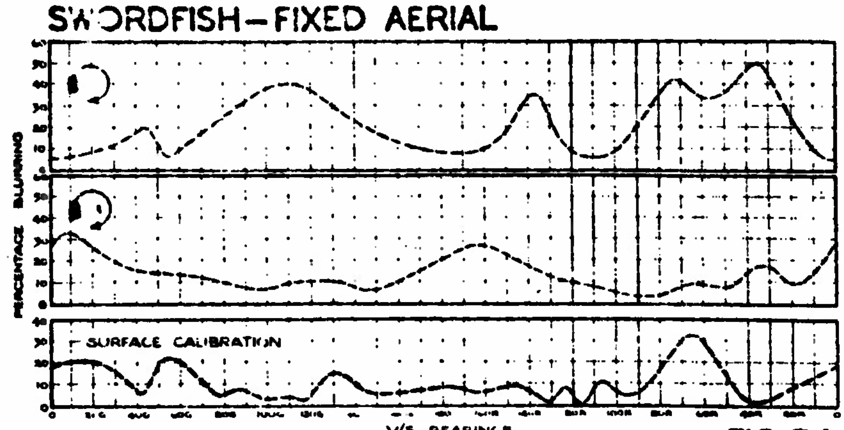


FIG. 50

OSCILLATION PATTERN OF ISOLATED HORIZONTAL LOOP

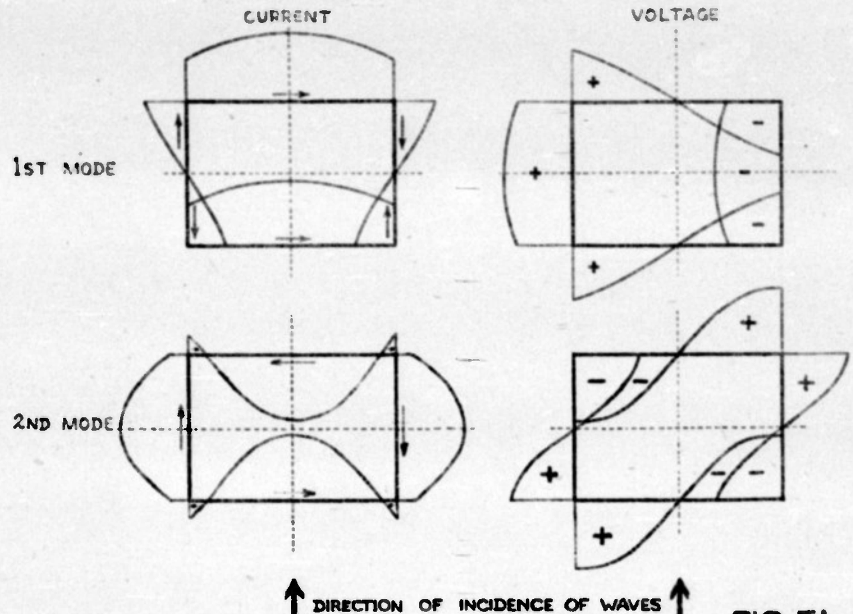


FIG. 51a

SIMPLIFIED DRAWING OF THE BRIDGE STRUCTURE OF H.M.S. SALTBURN

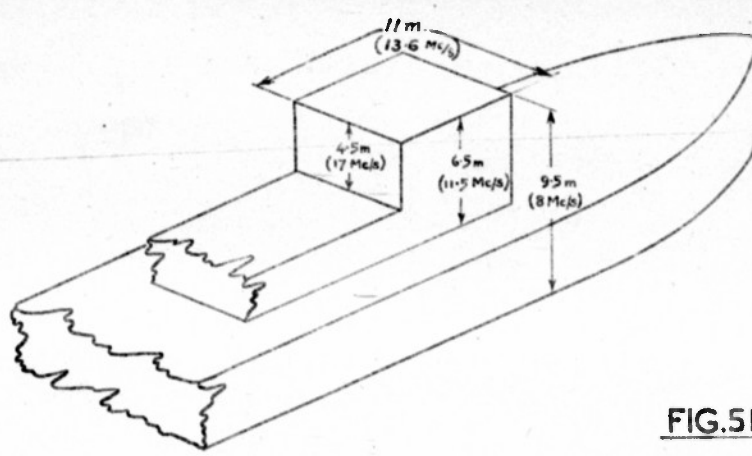


FIG. 51b

EFFECT OF RERADIATION OF HORIZONTAL LOOP ON POLARISATION ERRORS

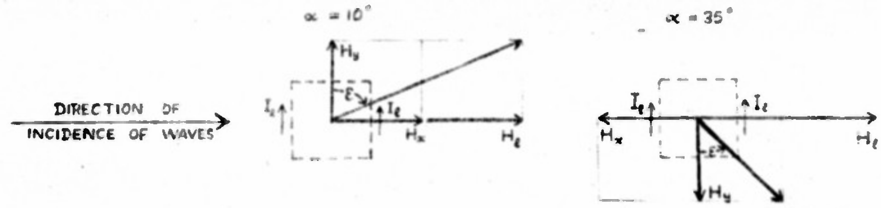


FIG. 51c

SIMPLIFIED PLAN OF HMS SALTBURN

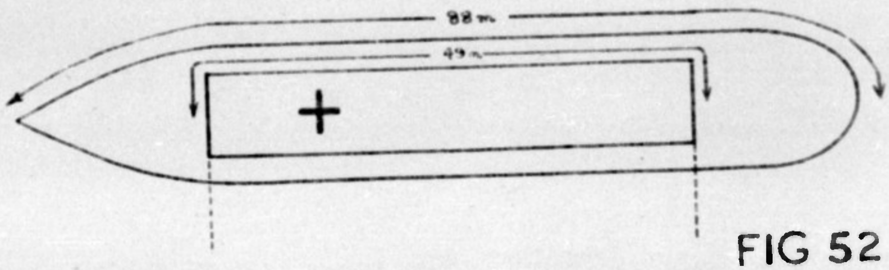
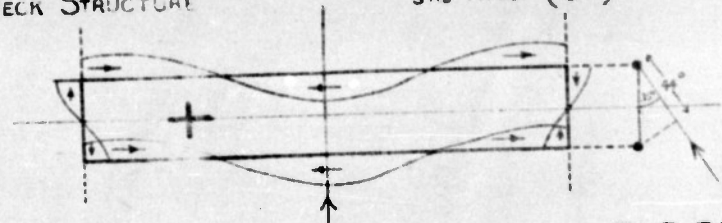


FIG 52

OSCILLATION PATTERN OF HORIZONTAL LOOP

BOAT DECK STRUCTURE

3RD MODE (3λ)



DIRECTION OF INCIDENCE OF WAVES

FIG 53a

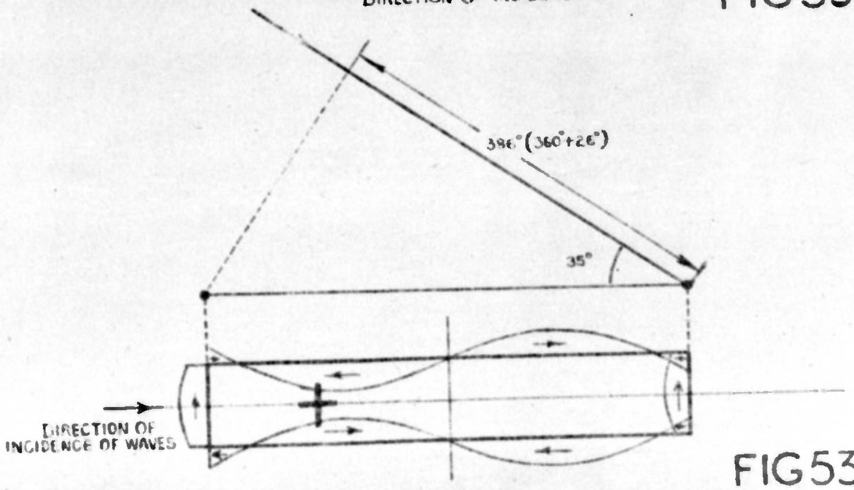
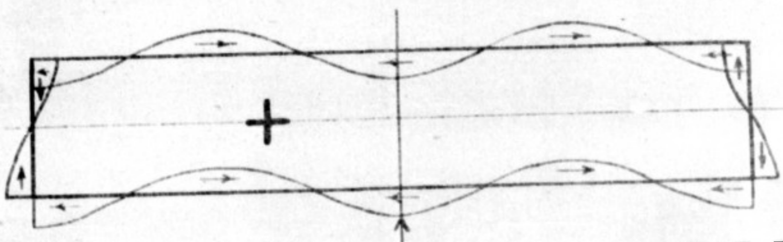


FIG 53b

OSCILLATION PATTERN OF HORIZONTAL LOOP

MAIN DECK

5TH MODE (5λ)



DIRECTION OF INCIDENCE OF WAVES

FIG 53c

VARIATION OF EQUIVALENT ANGLE OF TRAIL WITH FREQUENCY

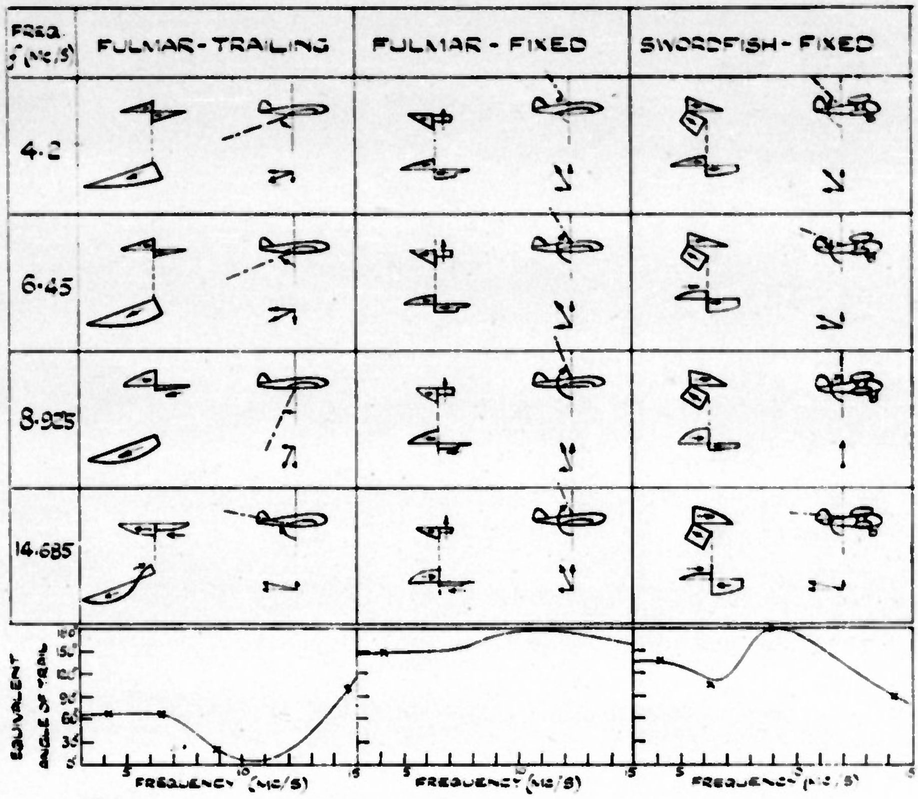


FIG. 54

VARIATION OF PSEUDO-BREWSTER ANGLE WITH FREQUENCY.

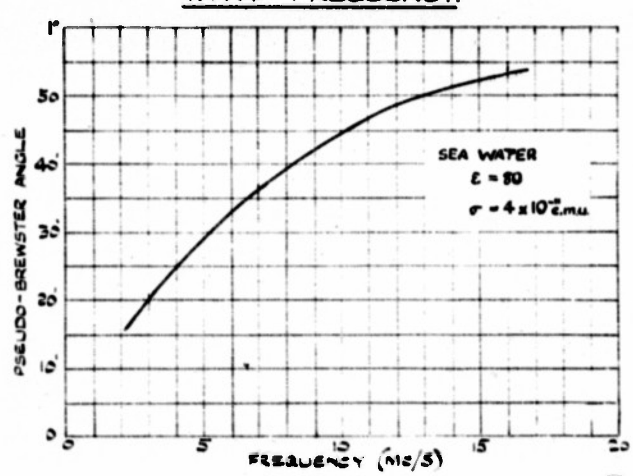
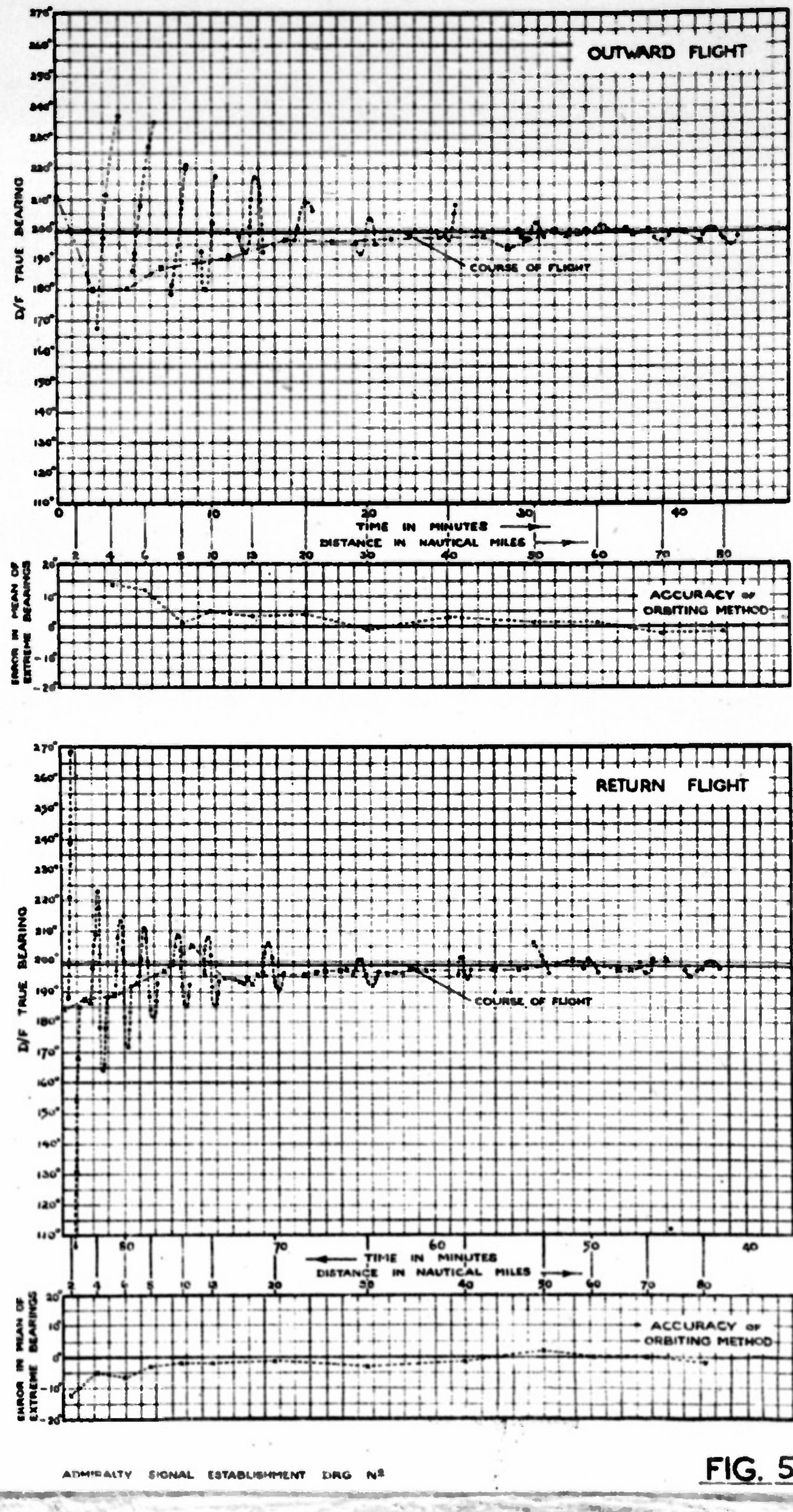


FIG: 55

D/F ORBITING METHOD
(TEST RUNS)

FULMAR — TRAILING AERIAL　　FREQUENCY 4·2 MC/S

SPEED 160 KNOTS　　HEIGHT 5000 FT



ADMIRALTY SIGNAL ESTABLISHMENT DRG Nº

FIG. 56

D/F ORBITING METHOD
(TEST RUNS)

HEIGHT 5000 FT

FULMAR- FIXED AERIAL FREQUENCY 4·2 MC/S

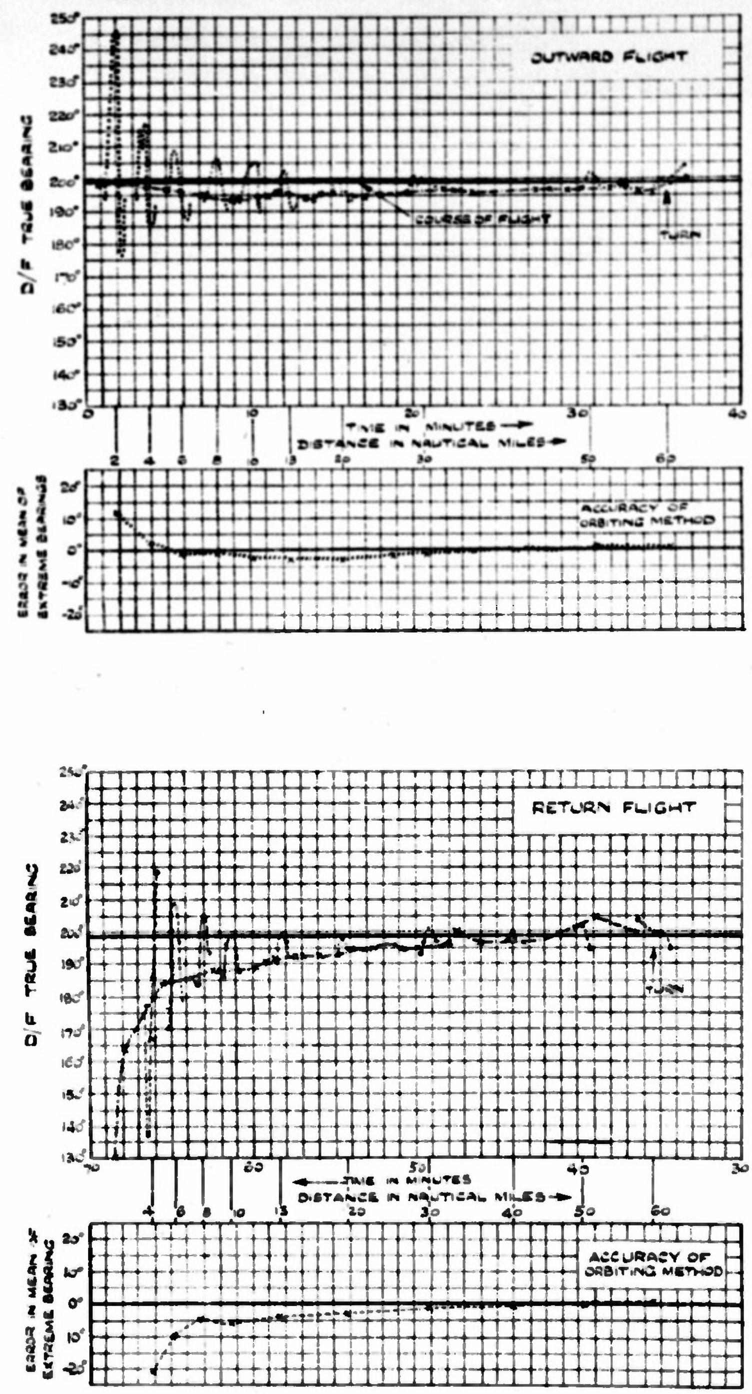


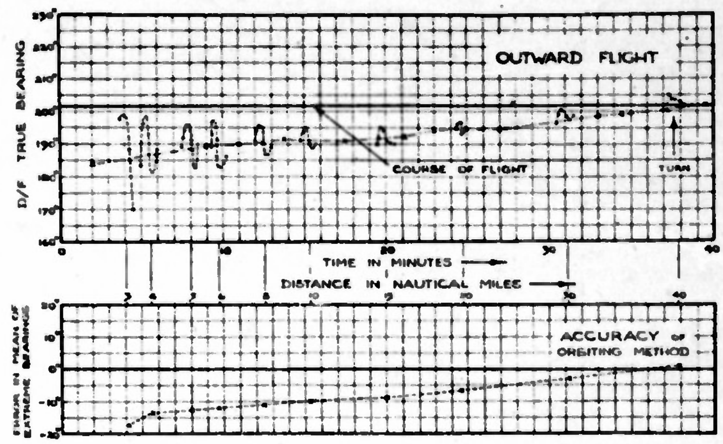
Fig. 57

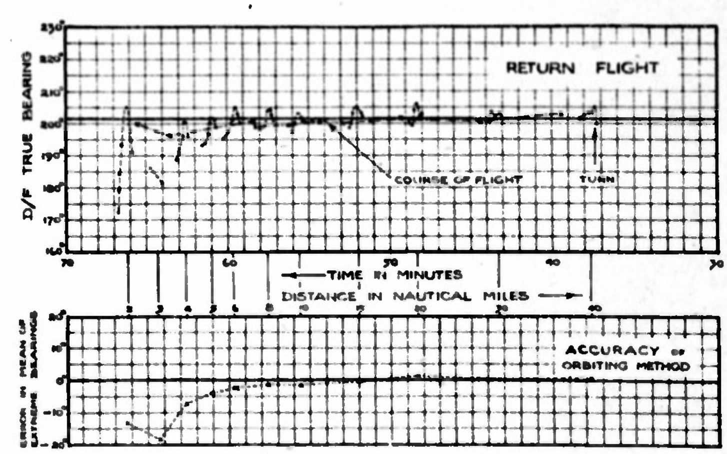
76-

D/F ORBITING METHOD
(TEST RUNS)

SWORDFISH — FIXED AERIAL FREQUENCY 4·2 MC/S

HEIGHT 3000 FT





ADMIRALTY SIGNAL ESTABLISHMENT DRG. Nº

FIG. 58

97-

D/F ORBITING METHOD

(TEST RUNS)

HEIGHT 5000 FT

FULMAR - TRAILING AERIAL

FREQUENCY 14·685 MC/S

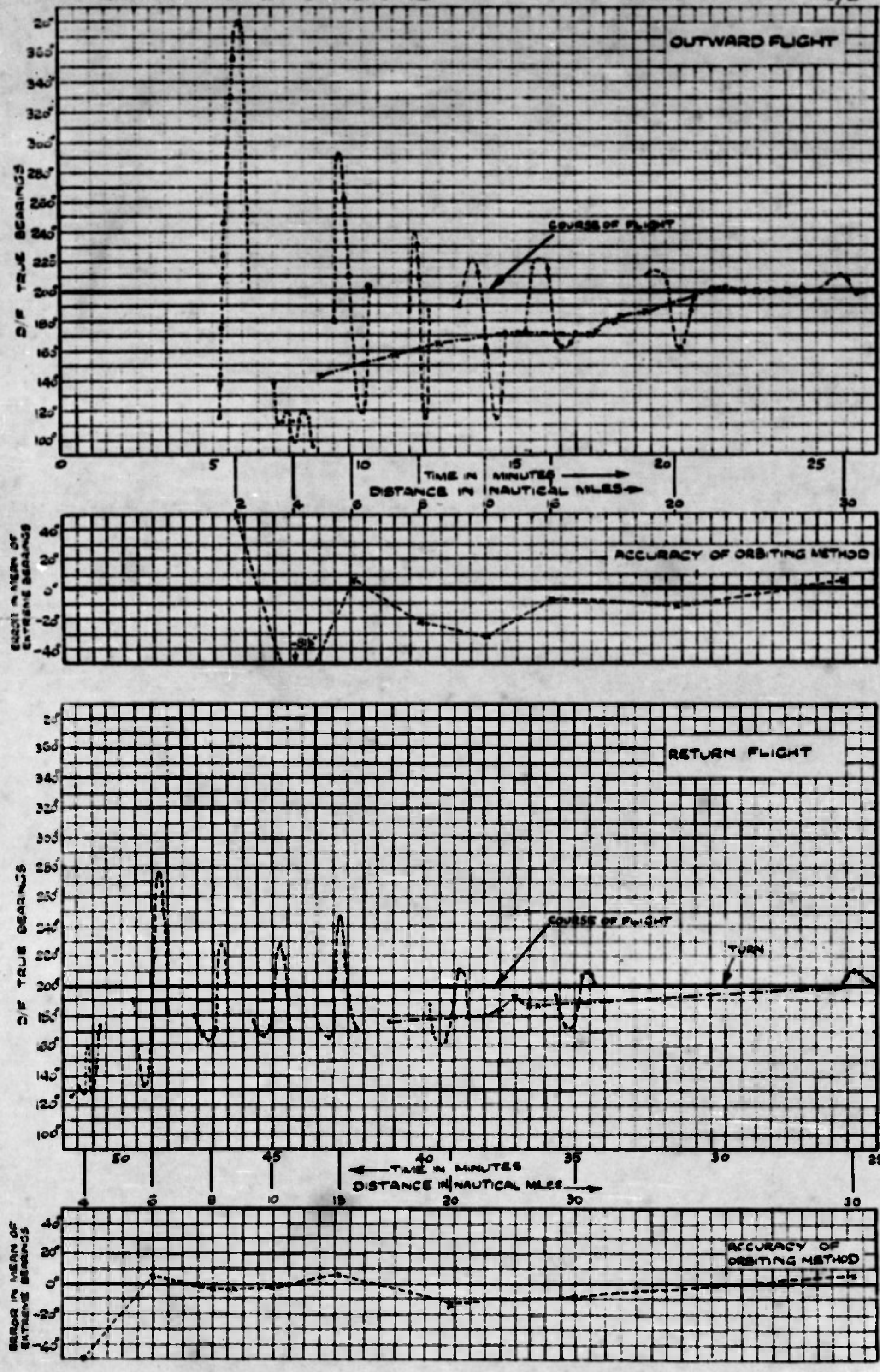


Fig. 59

VARIATION OF MAXIMUM POLARISATION ERRORS WITH DISTANCE FOR CONSTANT ALTITUDE OF FLIGHT

FULMAR - TRAILING AERIAL

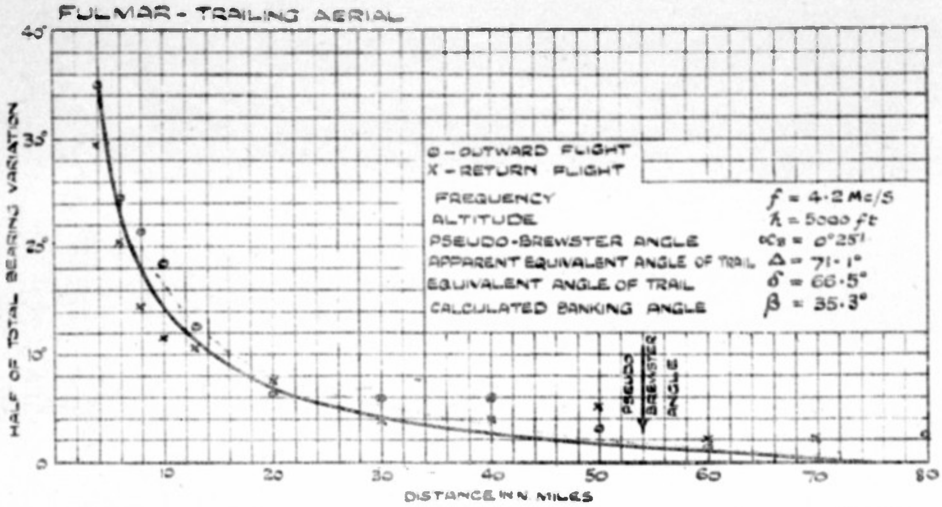


Fig 60

FULMAR - FIXED AERIAL

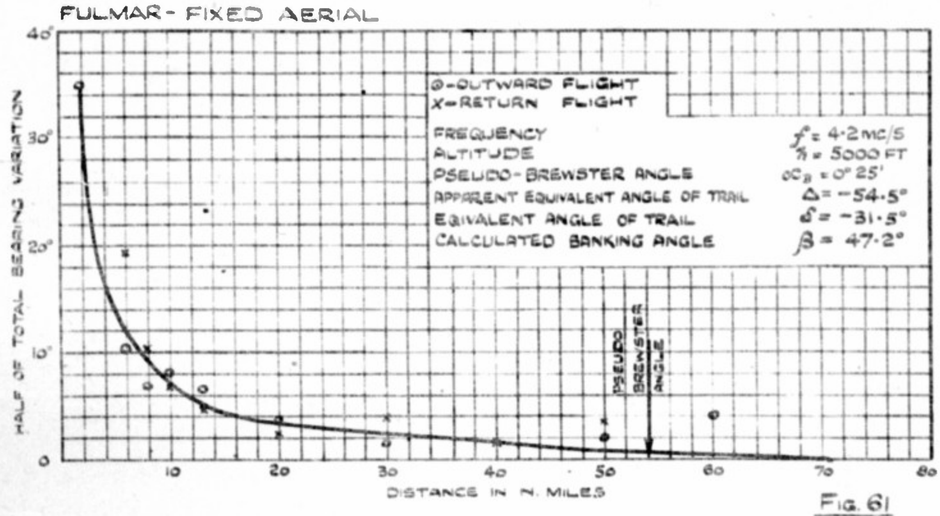


Fig. 61

SWORDFISH - FIXED AERIAL

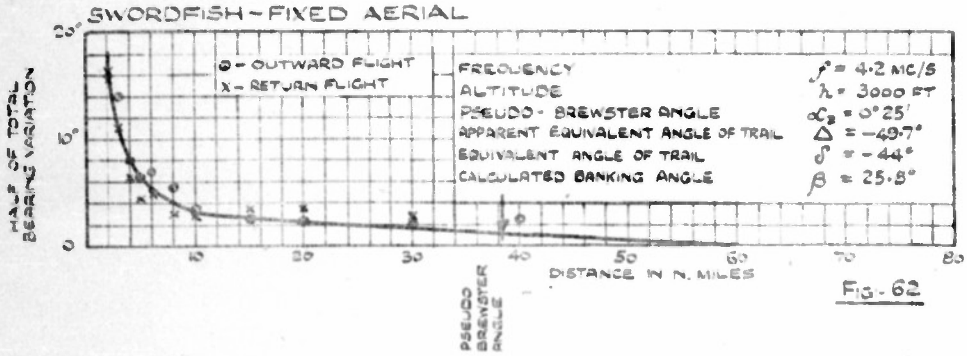


Fig. 62

VARIATION OF POLARISATION ERRORS WITH DISTANCE FOR CONSTANT ALTITUDE OF FLIGHT.

FULMAR - TRAILING AERIAL

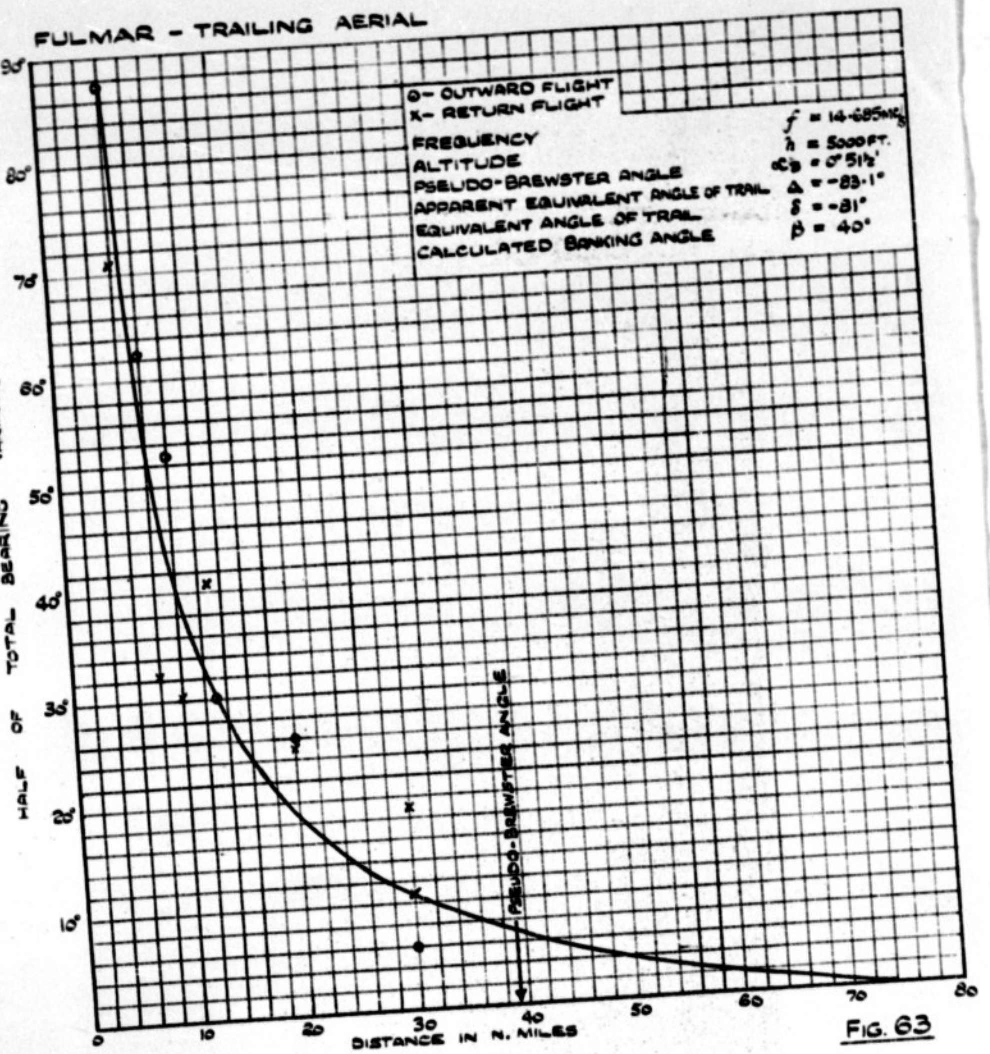
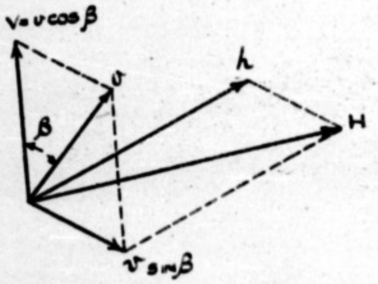


FIG. 63

APPARENT EQUIVALENT ANGLE OF TRAIL

DUE TO BANKING OF AIRCRAFT.



$$\tan\Delta = \frac{H}{V}\ ; \qquad \tan\delta = \frac{h}{v}\ ; \qquad \cos\beta = \sqrt{\frac{\tan^2\delta + 1}{\tan^2\Delta + 1}}\ ;$$

Fig. 64

GEOMETRICAL DETERMINATION OF AEROPLANE EFFECT ERRORS

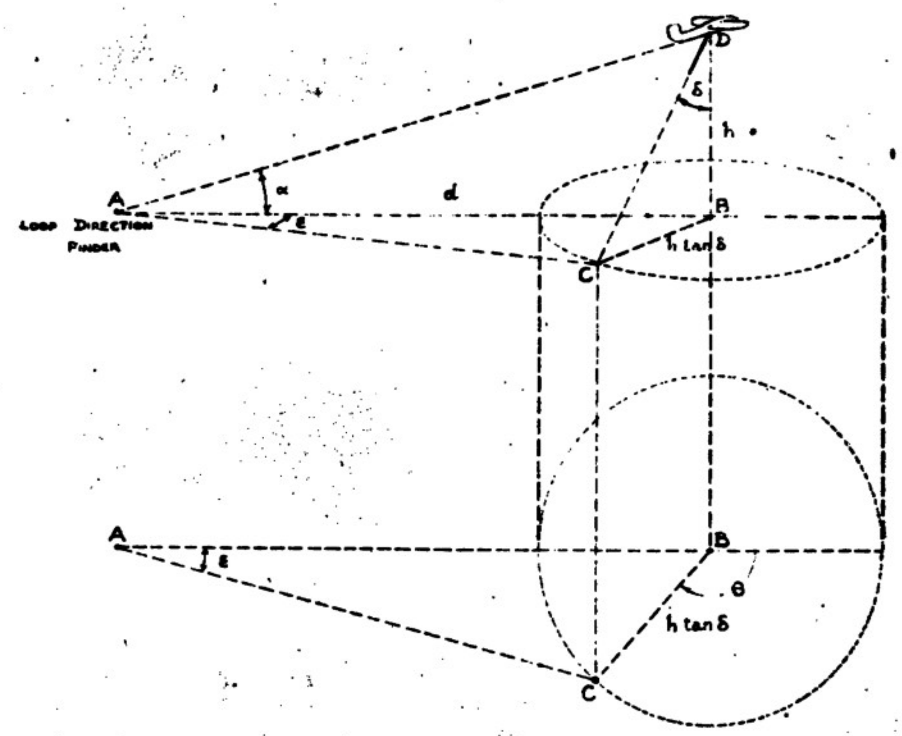


FIG. 65

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9393

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TITLE: Theoretical and Experimental Investigation of the Performance of Shipborne Fixed Crossed Loop H/F D/F Applied to Aircraft Navigation

AUTHOR(S): Struszynski, W.; Mugridge, A. H.; Wooley, J. C.
ORIGINATING AGENCY: Admiralty Signal Establishment

PUBLISHED BY: (Same)

ATI- 9393
DIVISION (None)
ORIG. AGENCY NO. M-780
PUBLISHING AGENCY NO. (Same)

DATE	DOC. CLASS.	COUNTRY	LANGUAGE	PAGES	ILLUSTRATIONS
Oct '48	Restr.	Gt. Brit.	Eng.	84	tables, diagrs, graphs, drwgs

ABSTRACT:

The development of a fixed antenna with pure vertical polarization for use in aircraft and the application of a special D/F procedure which requires orbiting the aircraft on the fixed true bearing, are two possible improvements for accuracy in present H/F D/F outfits. The design of a special transmitting antenna for use in aircraft, application of the orbiting method, and proposed future trials are discussed in detail. Results show that the present D/F procedure employed for surface transmissions is of little use for aircraft transmission.

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DIVISION: Electronics (3)
SECTION: Antennas (9)

ATI SHEET NO.: R-3-9-78

SUBJECT HEADINGS: Antennas, Aircraft (11063.5)

ATI- 9393

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